AUTOMOBILE ENGINEER

DESIGN PRODUCTION · MATERIALS

Vol. 48 No. 6 JUNE 1958 PRICE: 3s. 6d.

4,500 BLOWS A MINUTE SPEED WELD-TRIMMING JOBS

Though it only weighs 3 lbs., this Atlas Copco air-driven chipping hammer, type RRC 11 B, is a powerful little tool. Well-balanced, it can reach awkward spots with ease, and is light enough to be both operated and held with only one hand. With a striking rate of 4,500 blows a minute it has the ability to make a rapid job of any weld-trimming operation. Nor is any of its potential power lost by constant stoppages to clear away chippings. These are blown away by the tool itself; the air exhaust being directed towards the work.

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The Atlas Copco RRC 11 B is certainly a chipping hammer to increase production, while at the same time keeping running and maintenance costs at a minimum. Two features contribute towards this: the chisel nozzle is so designed that the piston strikes the chisel shank even while the tool is idling, eliminating cylinder breakages. And to ensure a high degree of reliability and capacity in relation to the air consumption, the hammer is valve-controlled.

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The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specialising in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world. For further details of the equipment featured here, contact your local Atlas Copco Company or Agent. If you have any difficulty, please write to:—Atlas Copco AB, Stockholm 1, Sweden, or Atlas Copco (Great Britain) Ltd., Beresford Avenue, Wembley, Middlesex.

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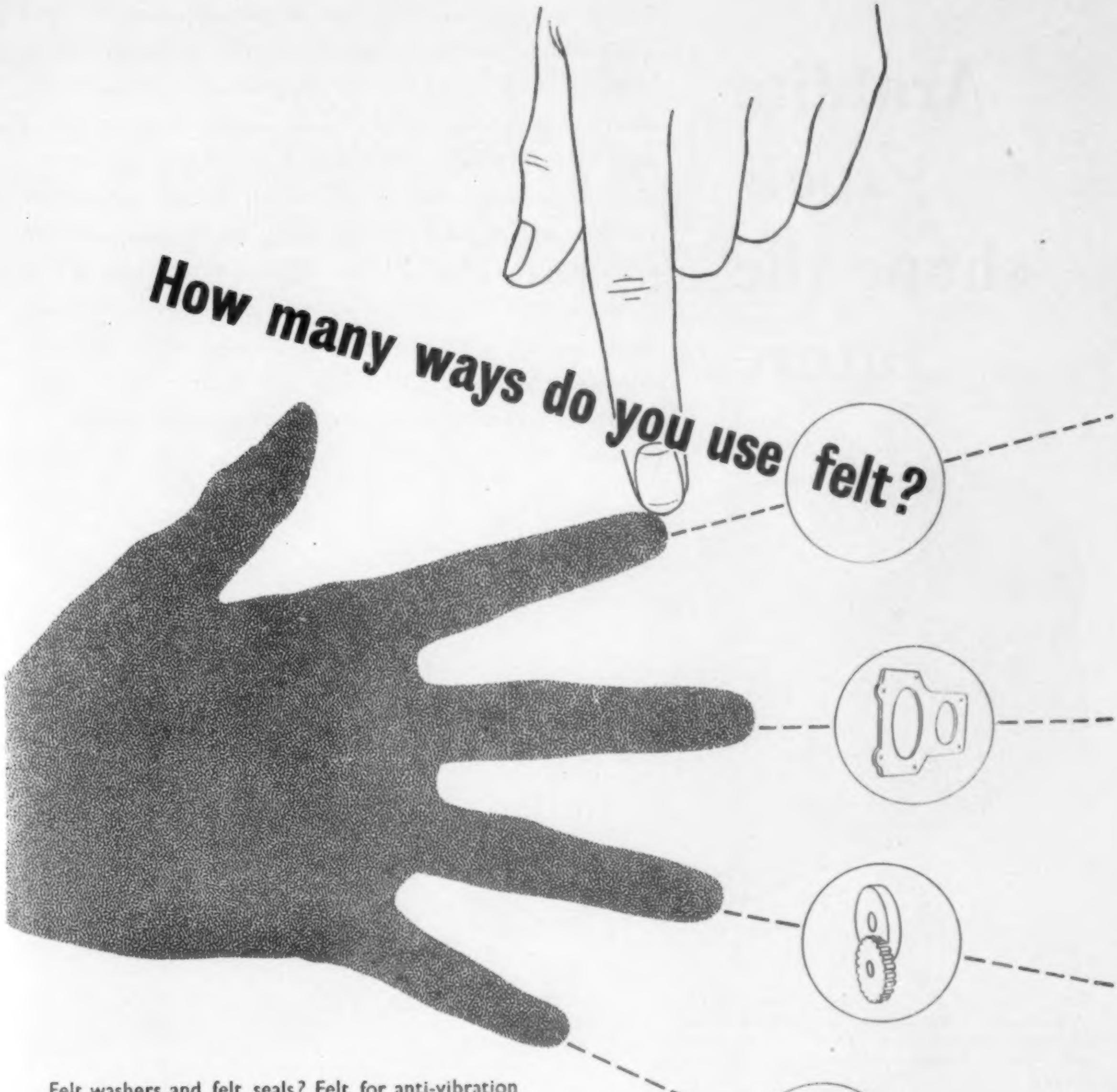

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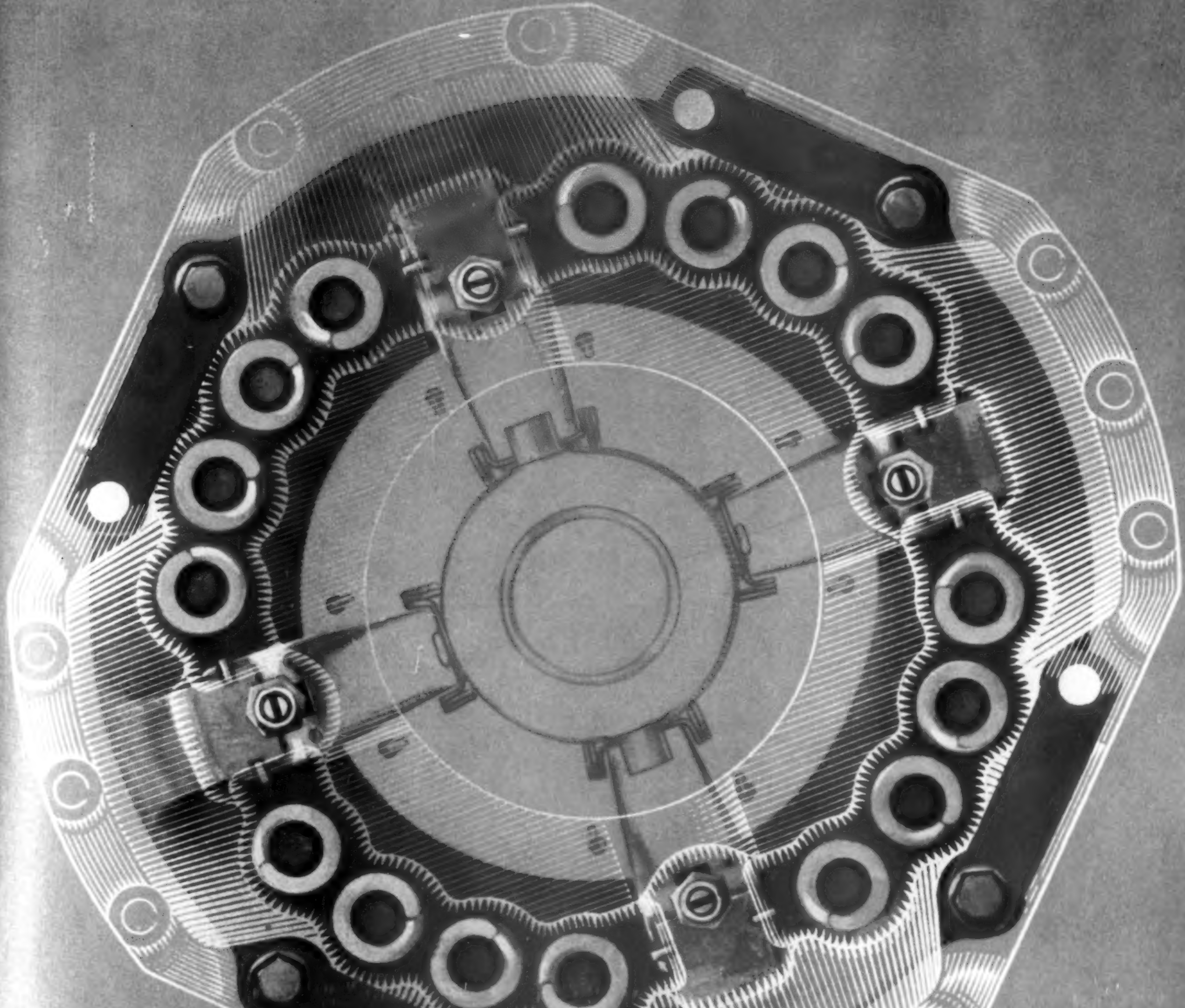
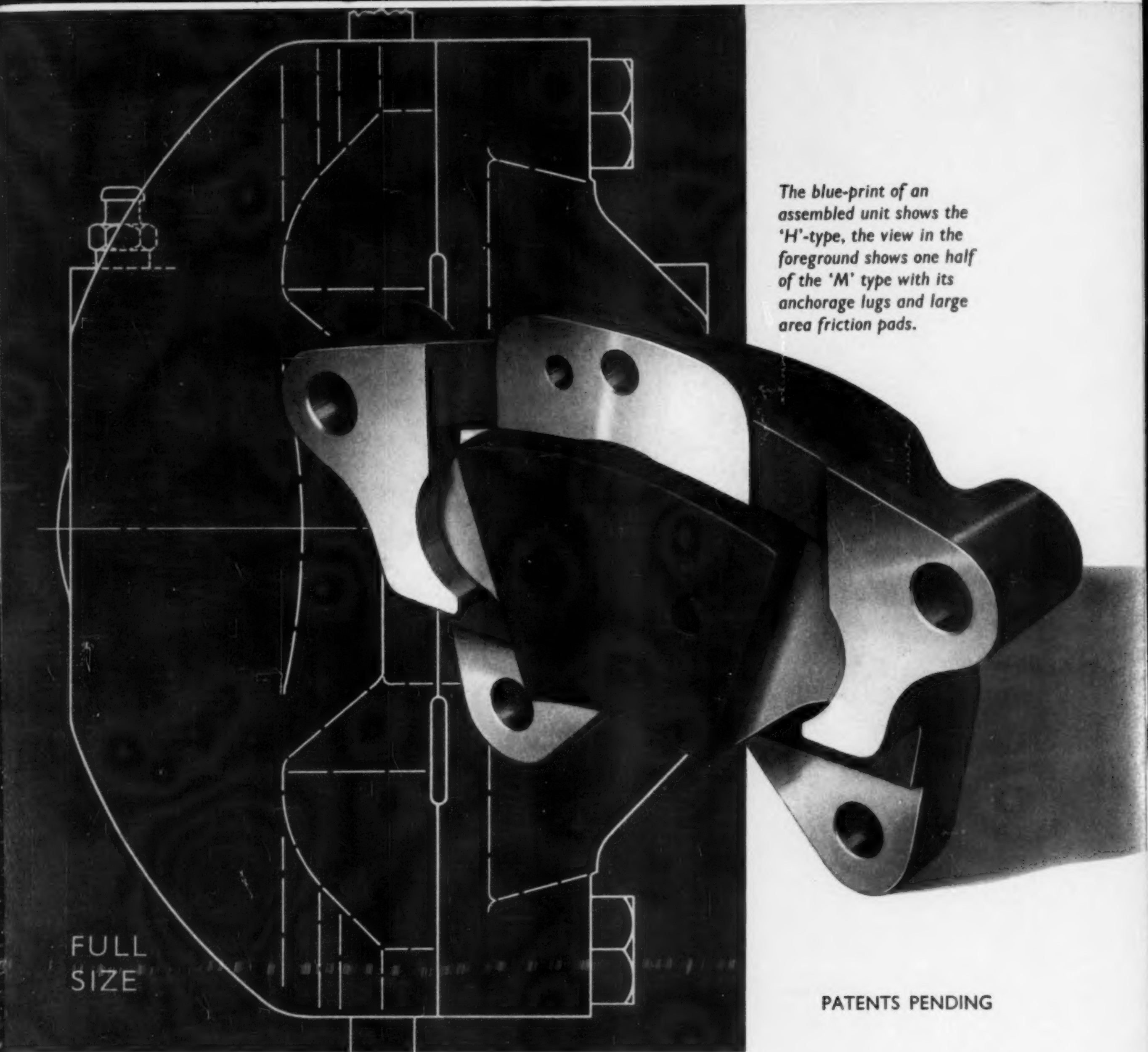
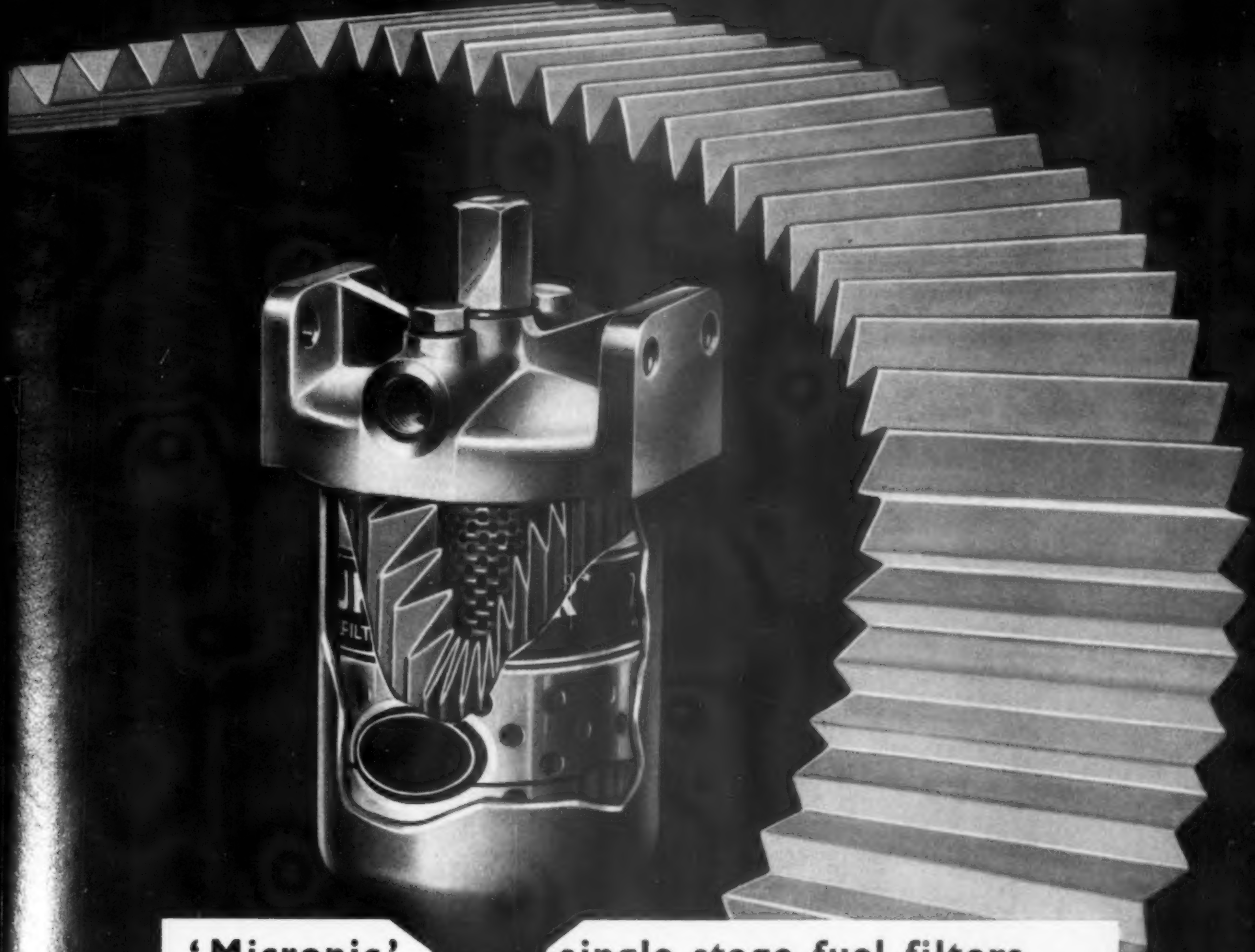
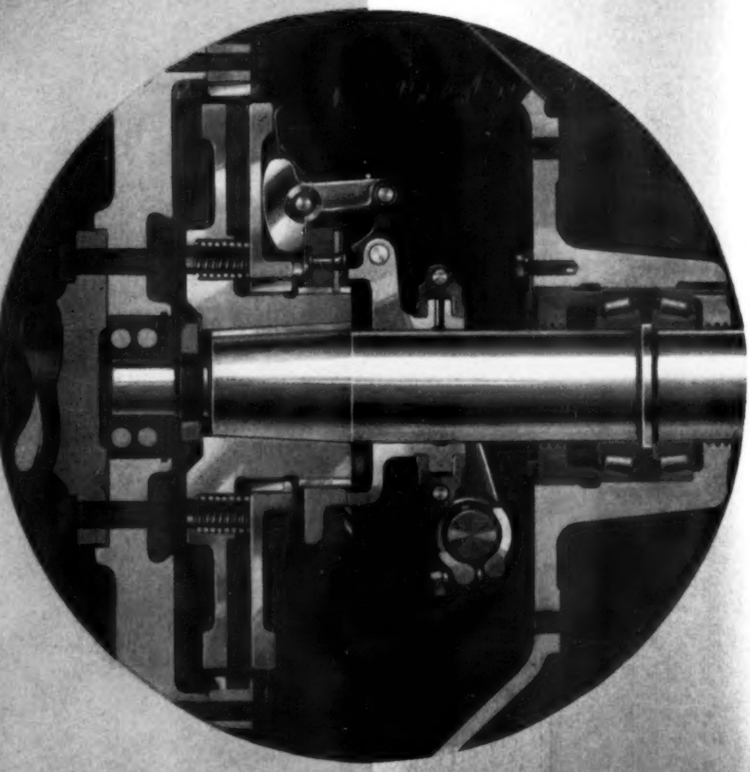




The blue-print of an assembled unit shows the 'H'-type, the view in the foreground shows one half of the 'M' type with its anchorage lugs and large area friction pads.

PATENTS PENDING





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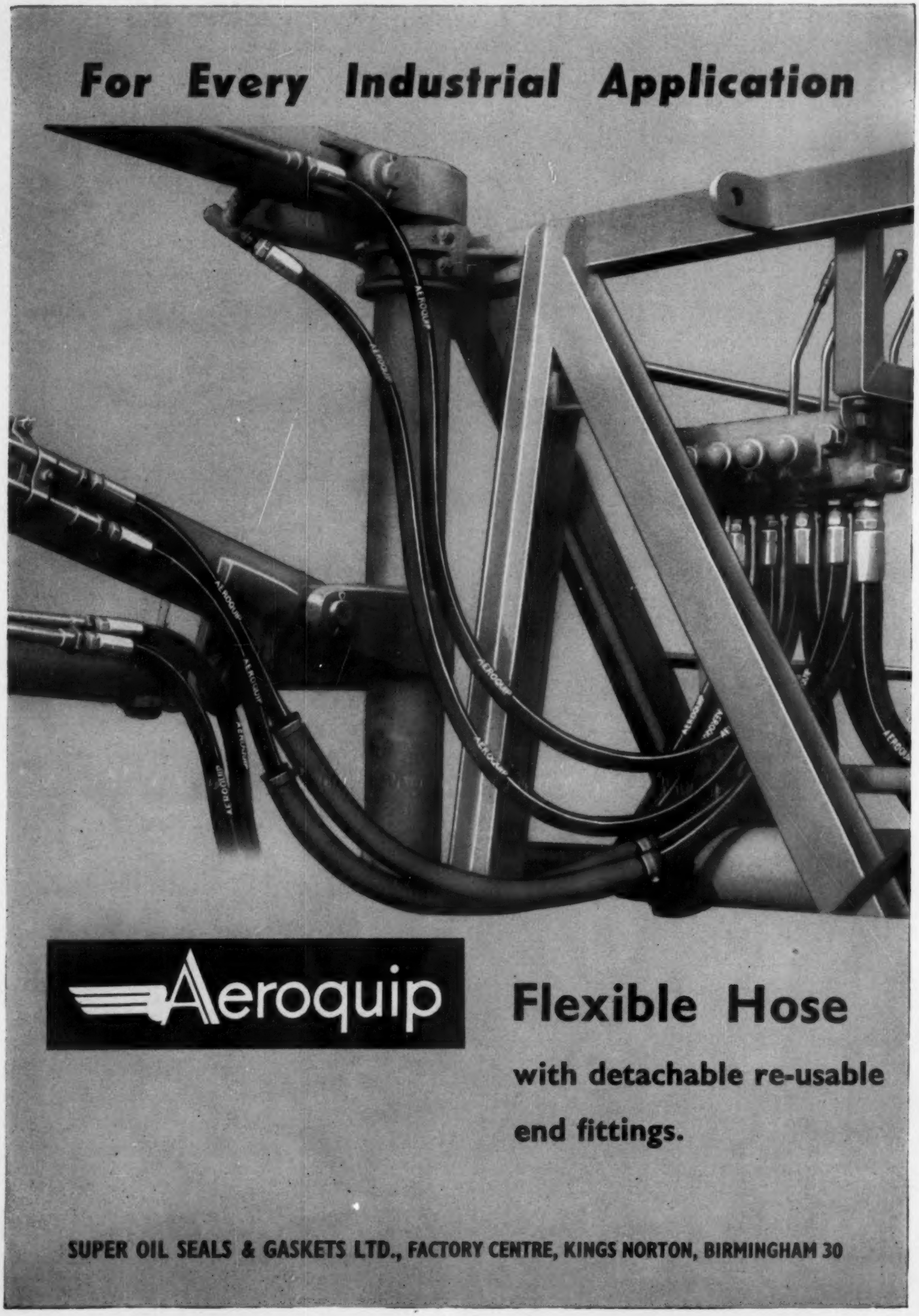
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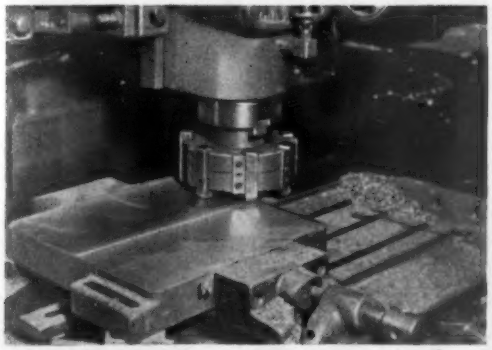

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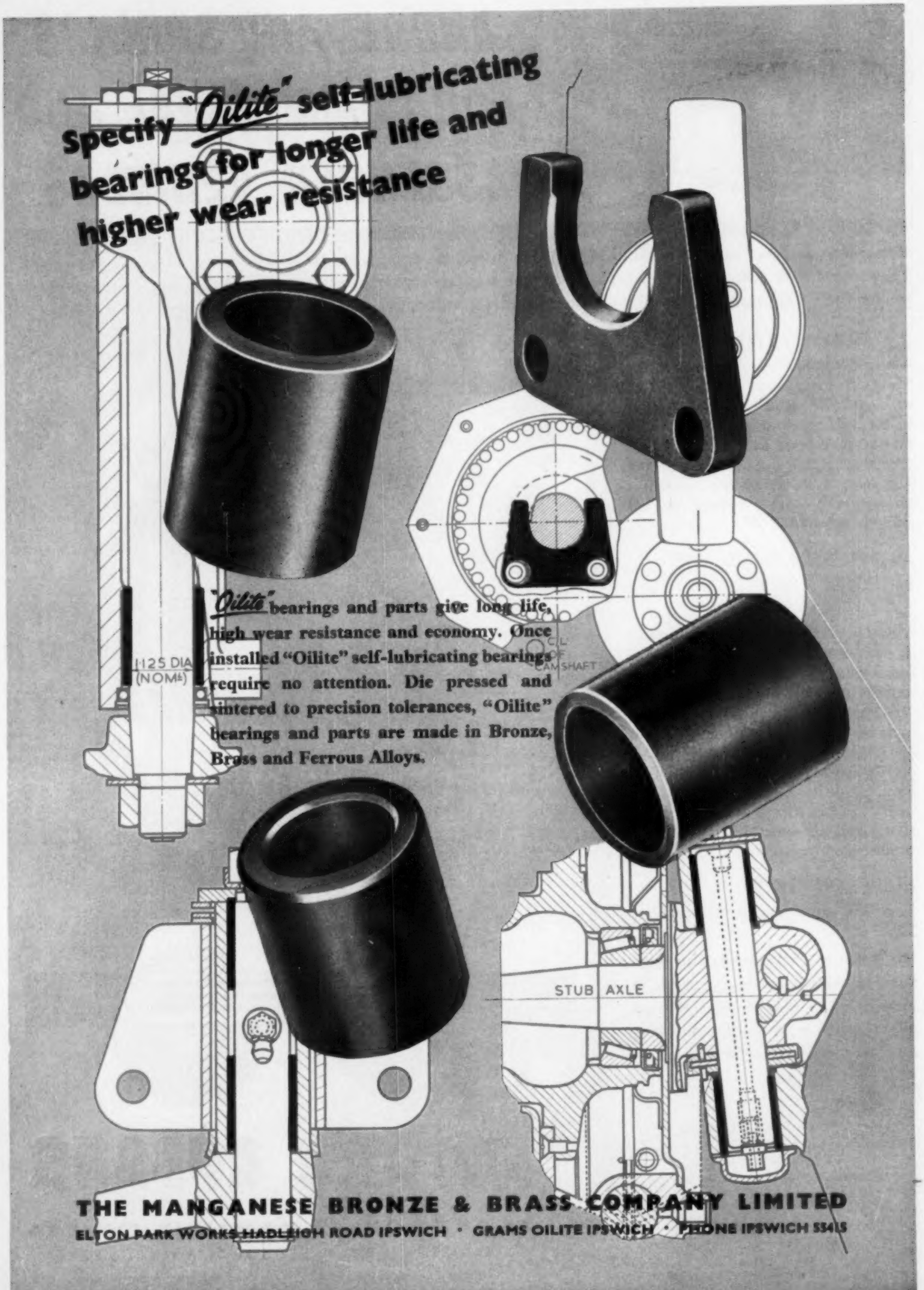

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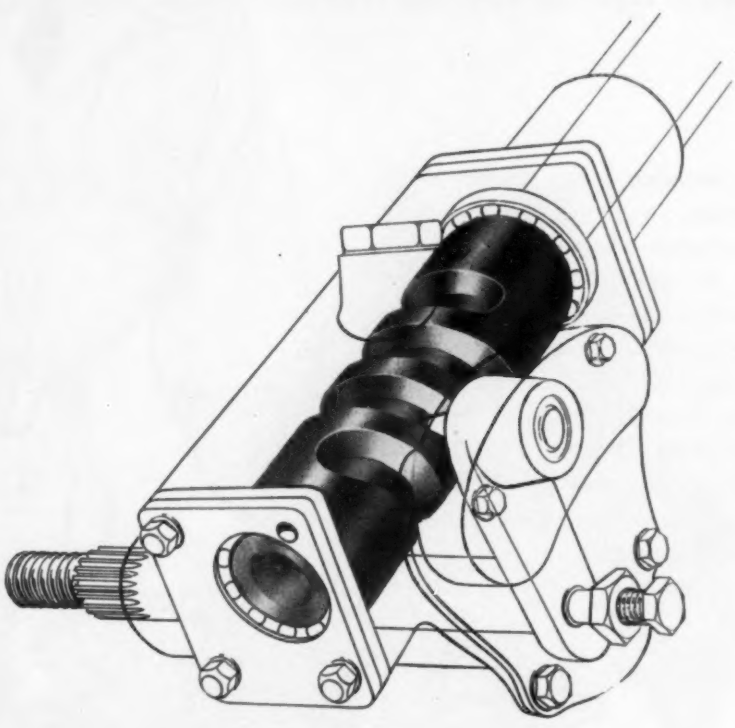

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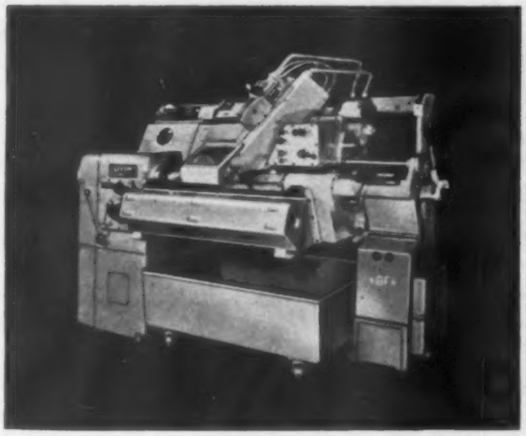

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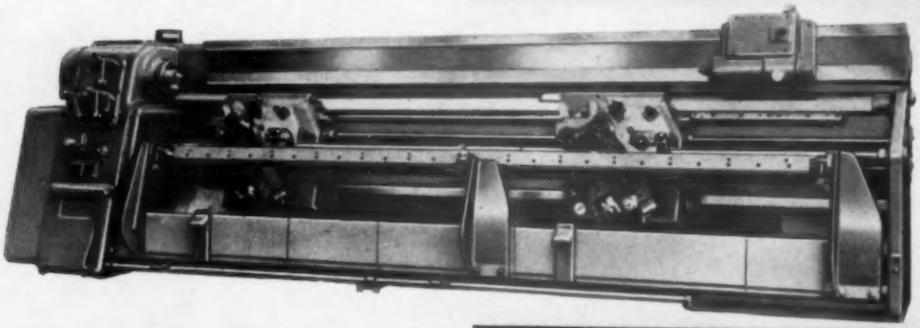

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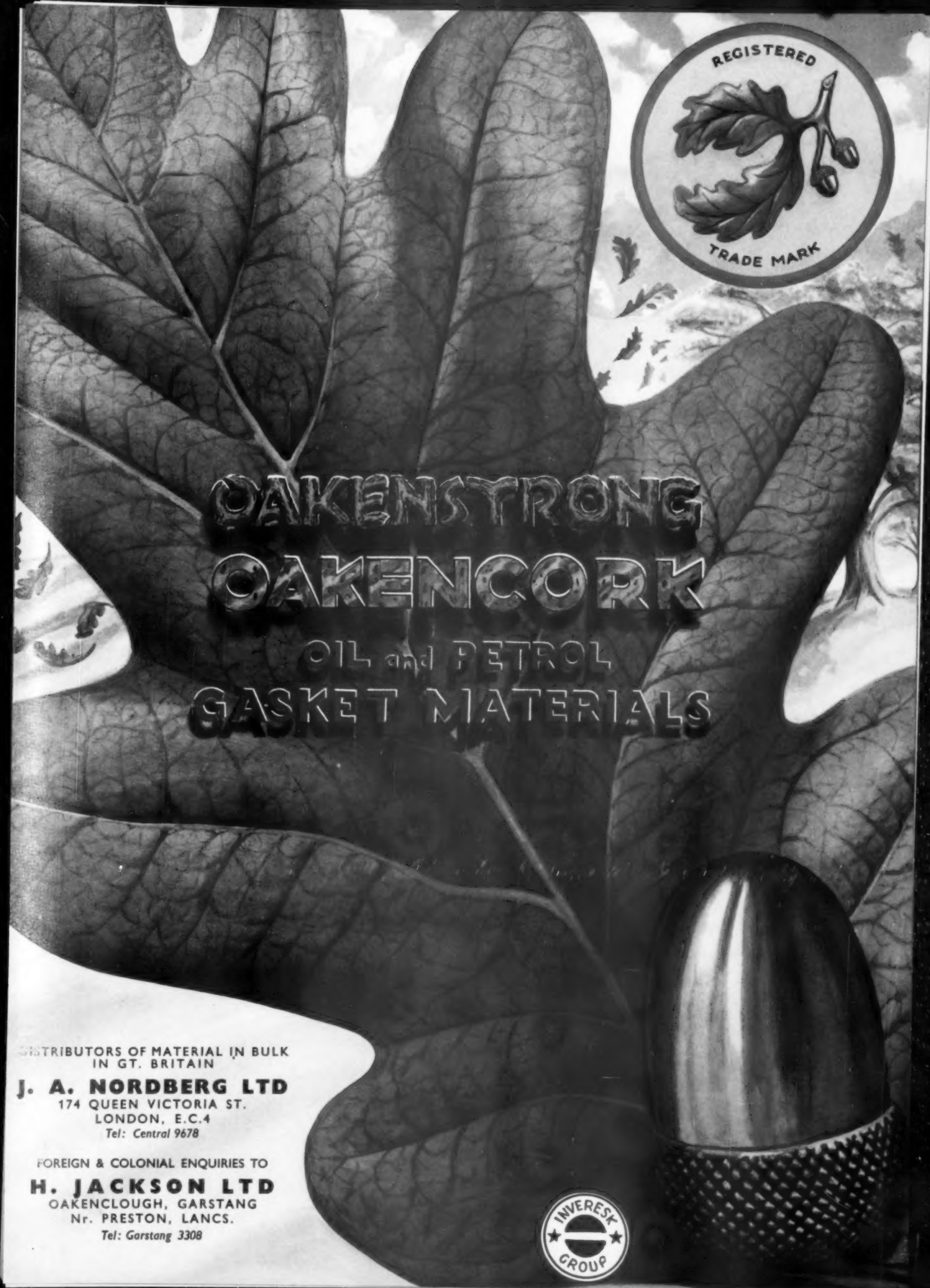
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Exclusive European distributors (except in Western Germany) for The Timken-Detroit Axle Division, Rockwell Spring & Axle Company, Detroit, Michigan, U.S.A.

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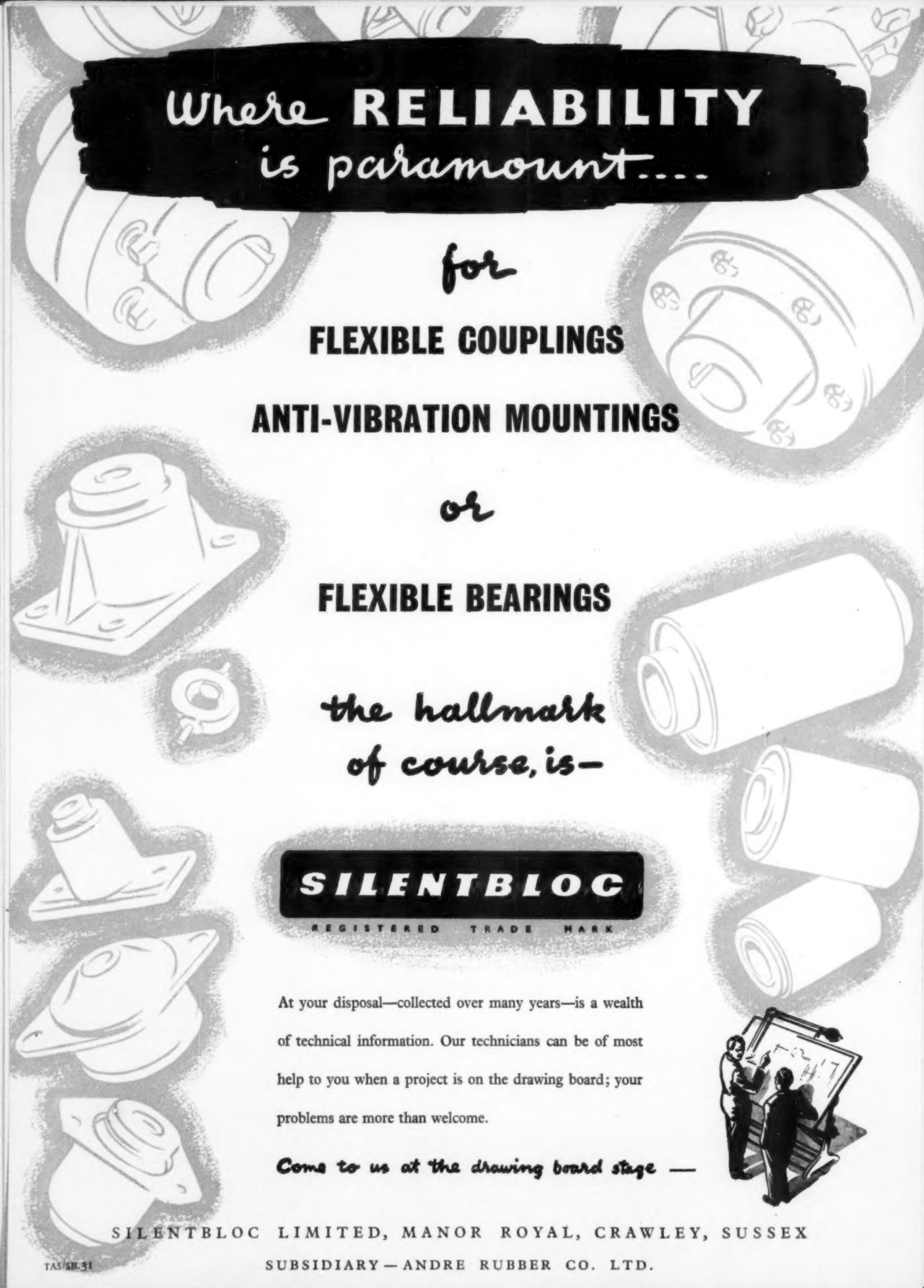
The Timken-Detroit comprehensive range of axles includes lightweight front axles, also front wheel drive axles to match the Timken-Detroit tandem rear axles for all-wheel drive. Transfer boxes are also available.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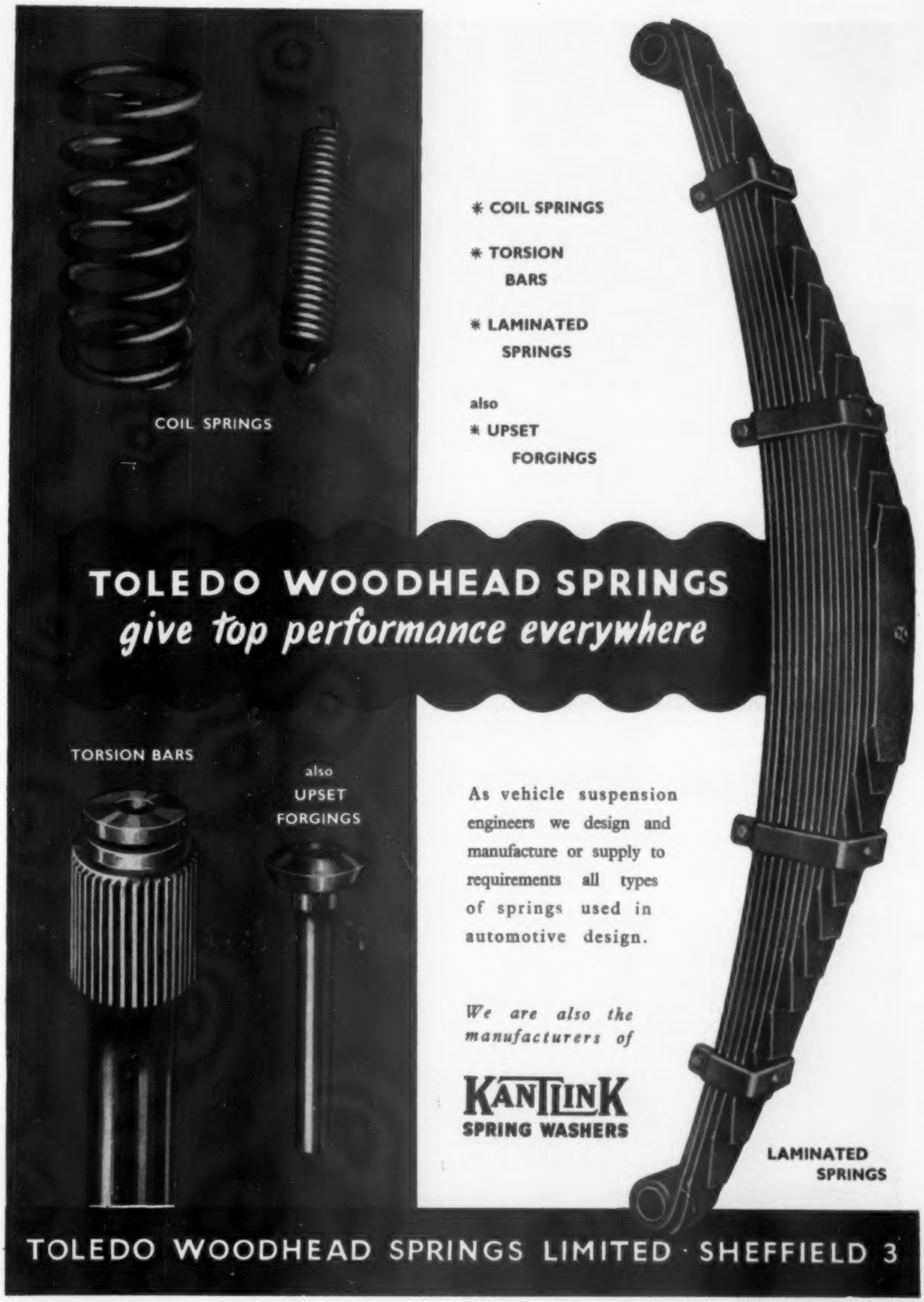
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Left: Timing Wheel Case. Casting weight 72 lbs.

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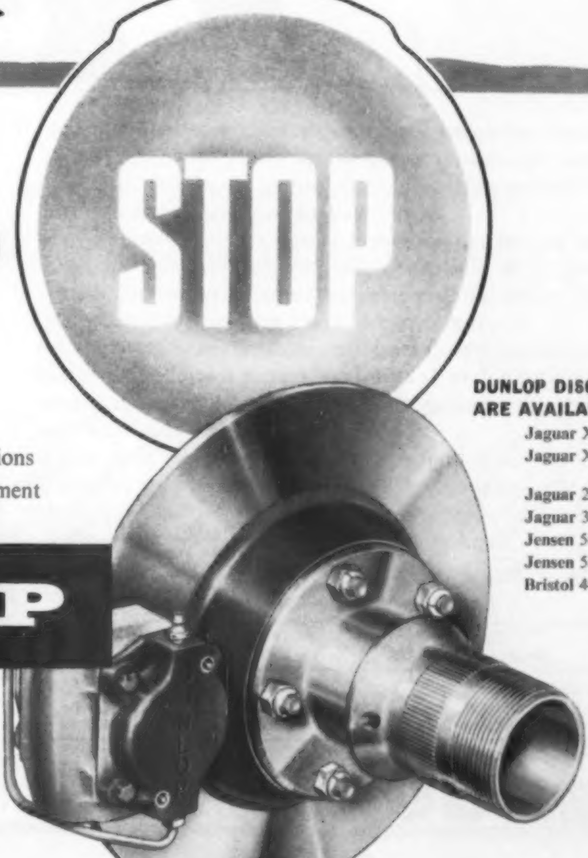

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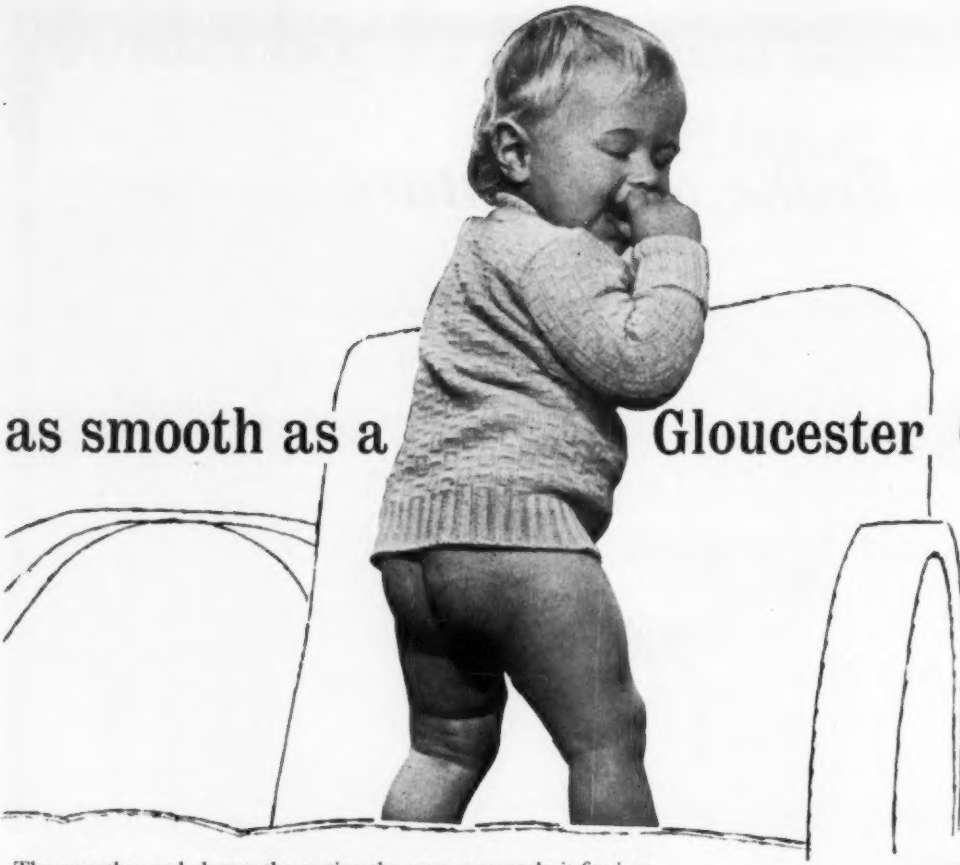

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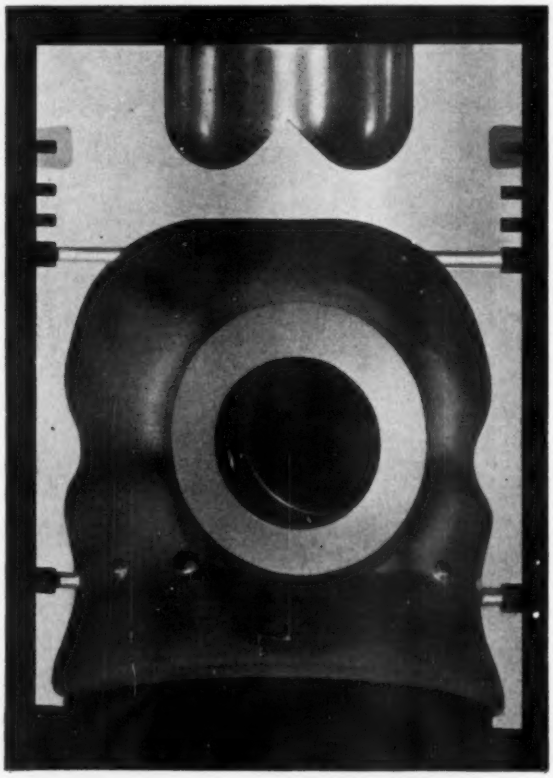

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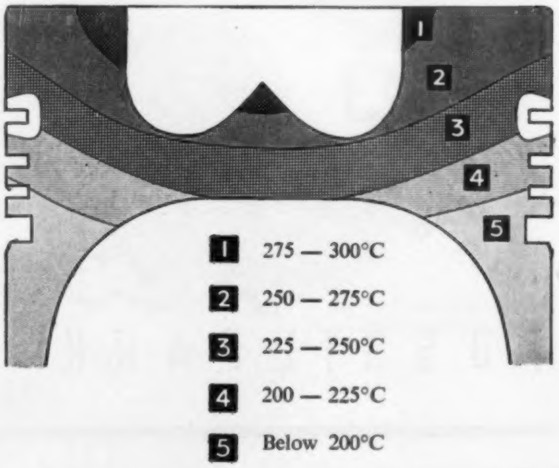
- That head thickness, coupled with correct blending into piston wall overcomes distortion of ring grooves. This has considerable bearing on blow-by and efficient oil control.



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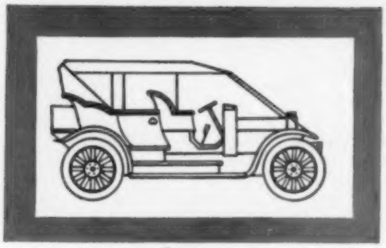

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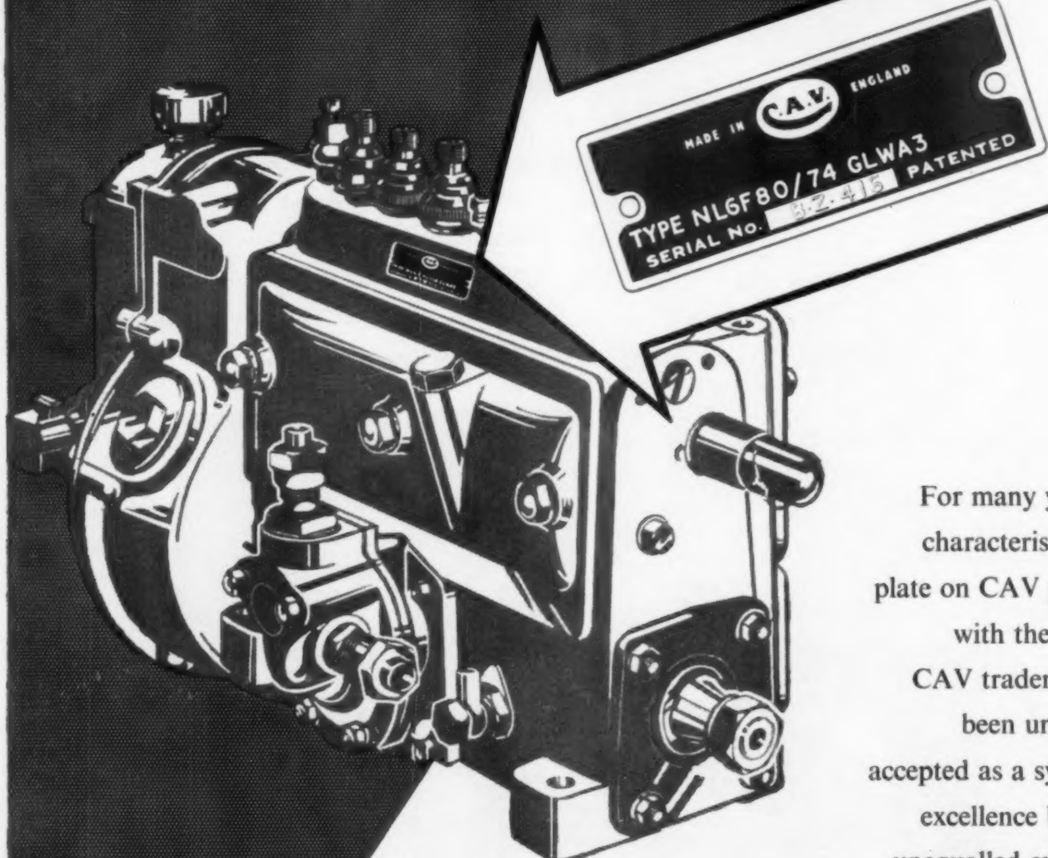

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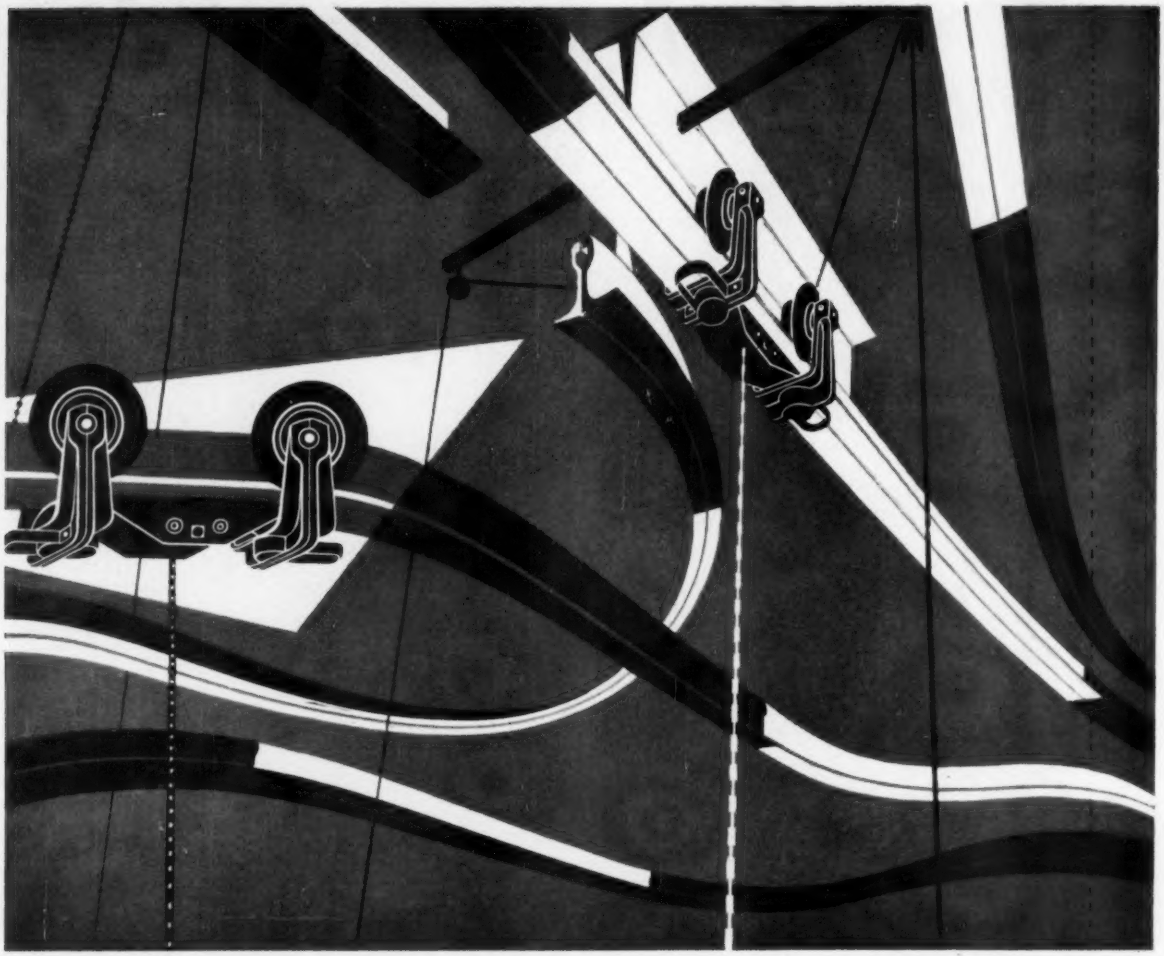

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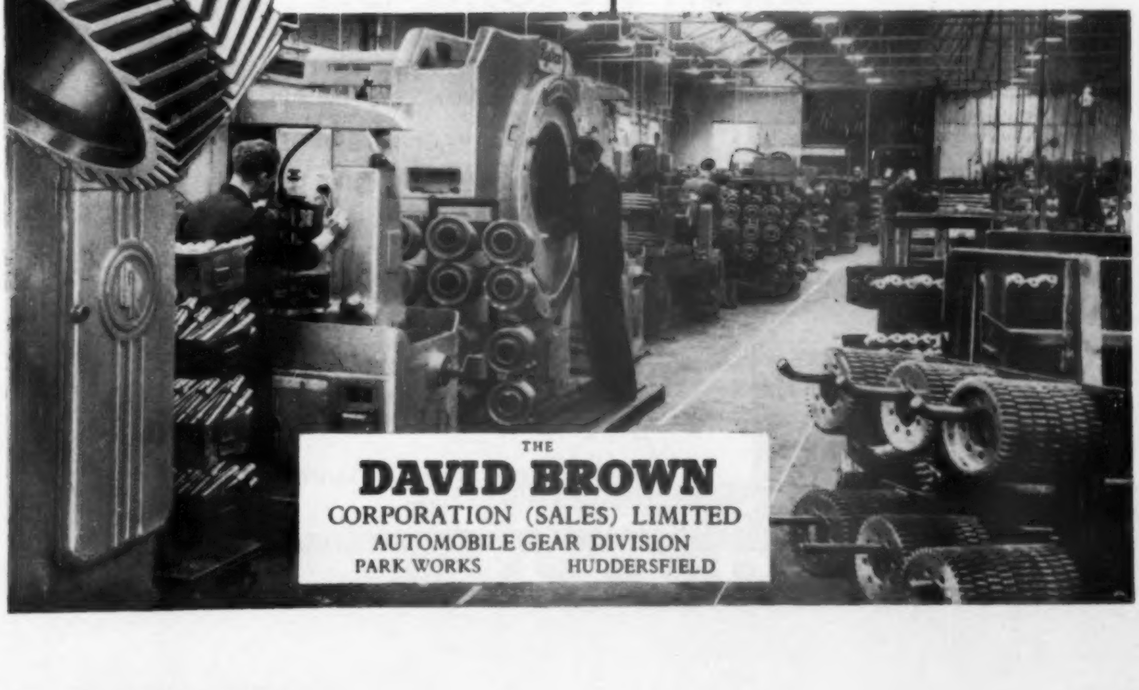


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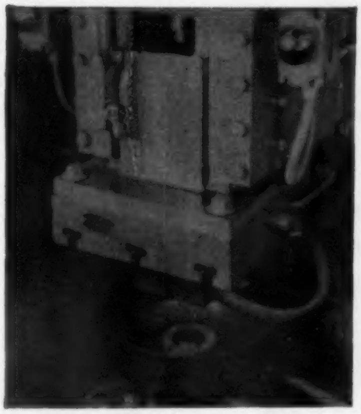

1. After the hub of the impeller has been pressed into its shell, the hub plate is welded inside the shell using a Metrovick 600 kVA projection welder.

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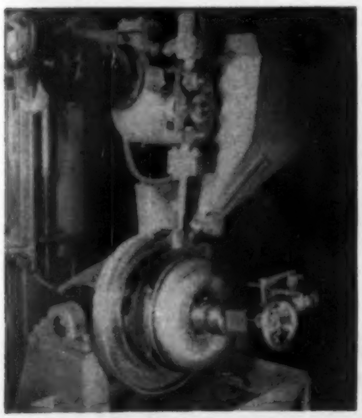

5. The completed clutch and flywheel assembly and the converter assembly are fitted together and then welded with a Metrovick submerged arc machine. This was specially designed for circumferential welds on Borg-Warner converter casings.

6. After testing the assembly for leaks a Metrovick Archway Type multi-spot unit is used to attach the blower. Sixteen spot welds are made with four air-operated heads. Control is by thyratron timer and ignitron contactor.

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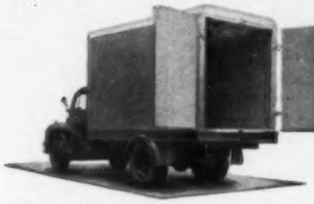

(Courtesy Birmingham Co-operative Society)

MEAT

In this meat van 'Duralumin' has been used throughout for the bodywork. It is easy to clean, non-toxic and can be kept free of smell with minimum attention, thus ensuring maximum hygiene in the transport of easily contaminated foodstuffs.

(Courtesy Chinnor Cement & Lime Co. Ltd.)

CEMENT

The strong, hardwearing, 'Duralumin' container of this tipping lorry is designed to carry 15½ tons of bulk cement. It is highly resistant to corrosion, can be easily cleaned out, and will not stain the cement.

(Courtesy Arthur Guinness, Son & Co. (Park Royal) Ltd.)

DRINK

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(Courtesy Duple Motor Bodies Ltd.)

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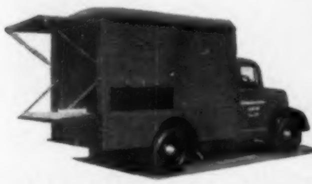

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VEGETABLES

An increase in cubic capacity without increasing weight or lowering structural strength—'Duralumin' makes this possible in vehicles like this roomy greengrocery van. Roller shutters, flooring, hinged flap and tailboard are all of 'Duralumin'.

(Courtesy Thomas Hedley & Co. Ltd.)

CHEMICALS

Lightweight corrosion-resistant 'Duralumin' was chosen for this 690 cu. ft. sectioned hopper which is designed to carry chemicals in bulk for detergent manufacture. An A.E.C. Mandator tractor with a 'Duralumin' cab hauls the load.

(Courtesy Ross Group Ltd.)

FISH

Less deadweight means more freight carried at lower cost! This lightweight road-rail container of 'Duralumin' makes bulk transport of fish easier and cheaper. Lined with 'MG5' alloy, its interior is easily cleaned, and brine will not corrode it.

(Courtesy London Brick Co. Ltd.)

BRICKS

A saving of 15 cwt. in deadweight and a 75% cut in maintenance costs have resulted from the use of 'Duralumin' in bodywork and Duraplank flooring of all London Brick Co. vehicles.

(Courtesy Newark Egg Packers Ltd.)

GRAIN

'Duralumin' is used throughout in the bodywork of this bulk grain transporter. The 480 cu. ft. 'Duralumin' hopper, fitted with tipping gear, is light in weight and enables a 10-ton payload to be carried.

(Courtesy R. A. Dyson & Co. Ltd., Liverpool)

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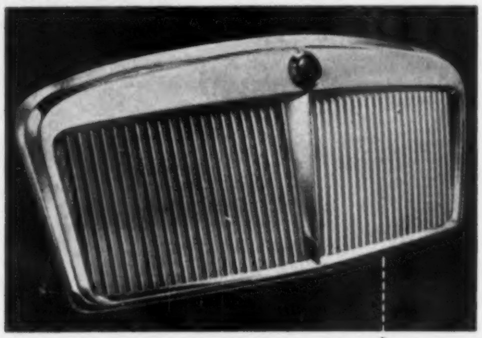

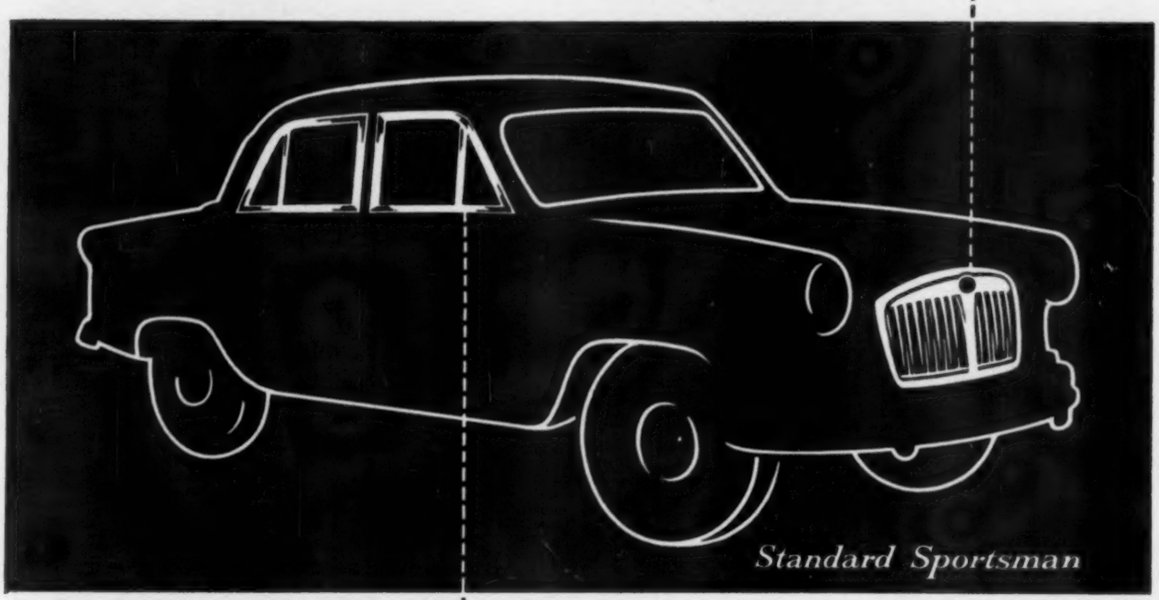
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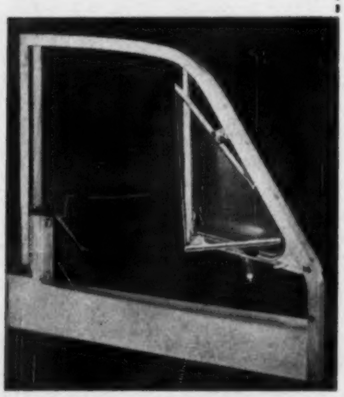

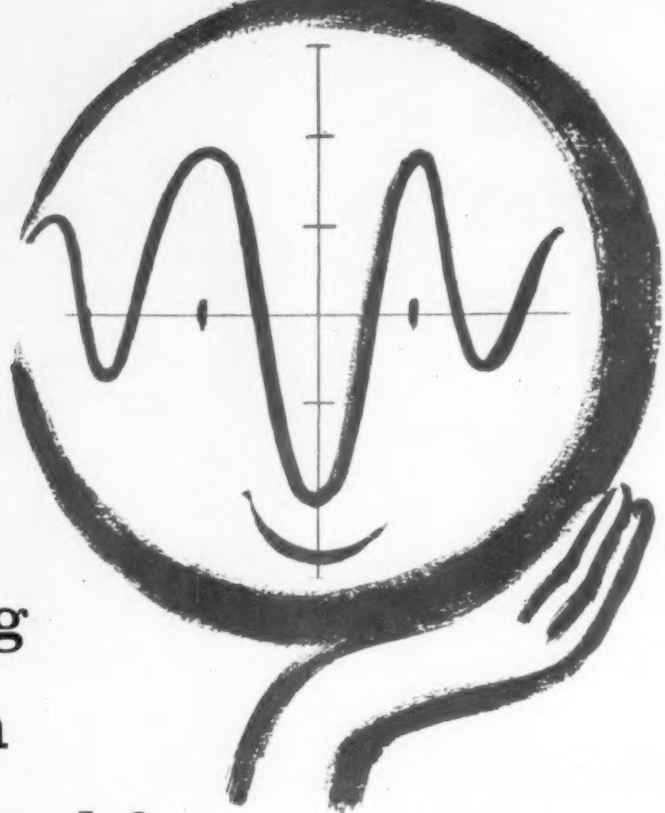

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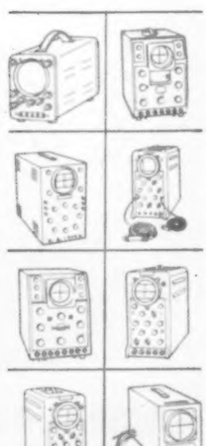

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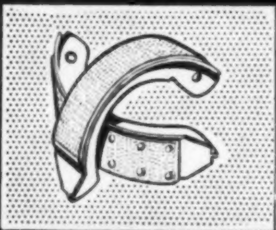

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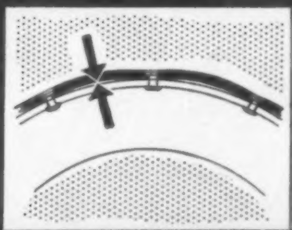

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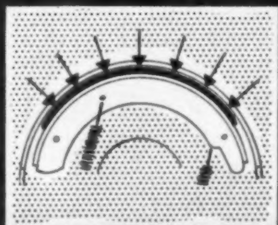

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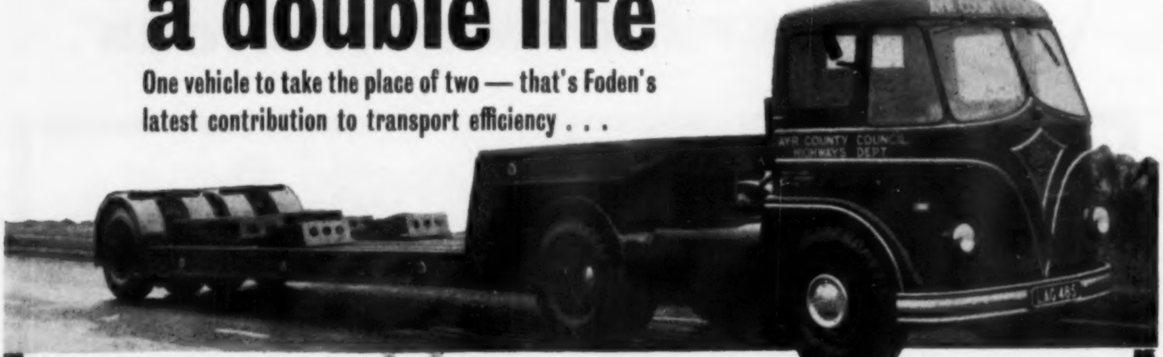

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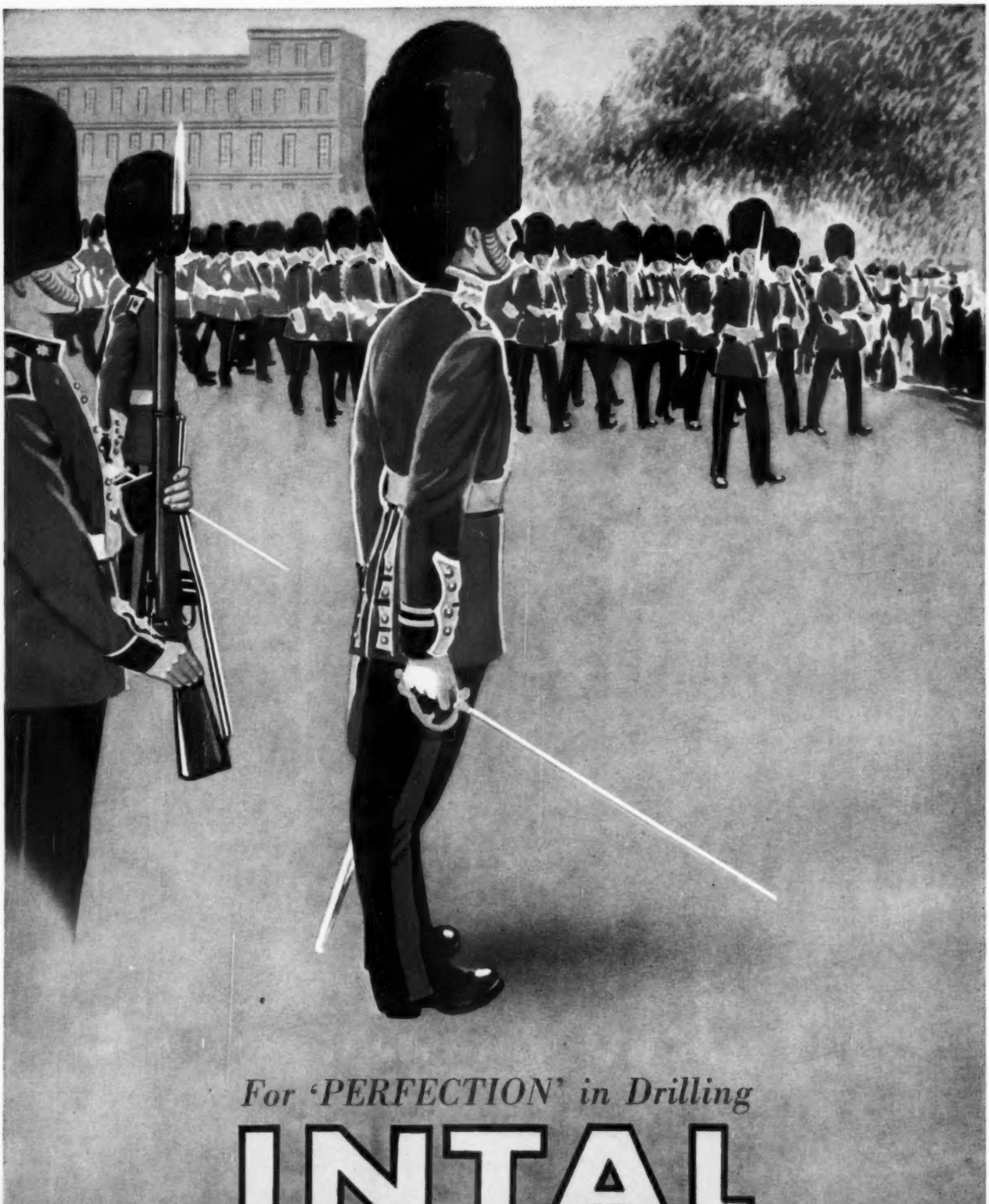

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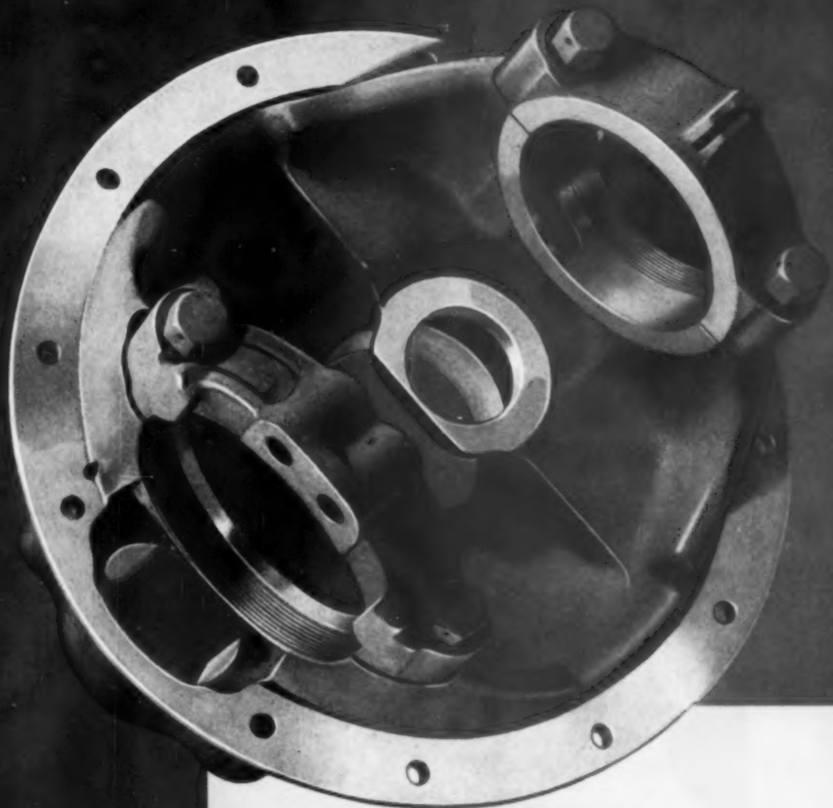

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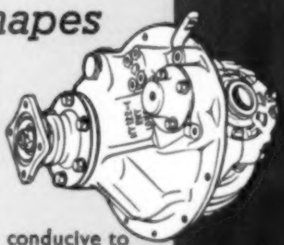

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Editor *J. B. Duncan*

Editorial Staff *T. K. Garrett, A.M.I.Mech.E. A.F.R.Ae.S.(Associate Editor)*

F. C. Sheffield

DESIGN MATERIALS **AUTOMOBILE ENGINEER** PRODUCTION METHODS WORKS EQUIPMENT

Aerodynamics and Stability

HITHERTO, the aerodynamic aspect of body design has received only scant attention, except for racing and sports cars. There are many reasons for this. Perhaps the most potent is that on motor vehicles there are so many mechanical features, such as wheel arches, suspension and steering linkages, that cannot be adapted to aerodynamic requirements, and therefore many engineering executives take the view that time devoted to the purely aerodynamic aspects of design and development would be wasted. Another is that, so far as air resistance, and therefore economy of fuel consumption, are concerned, there is little to be gained by good aerodynamic design, except at speeds in excess of about 45 m.p.h. In any case, few engineers in the motor industry have studied the fundamental principles of aerodynamics, and still fewer have had practical experience in the application of this science to engineering design; for this reason, attempts to streamline cars have in many instances been crude and ineffective.

However, there are gains in addition to low drag to be had from good aerodynamic design. One is stability in side winds, particularly in gusts, and another is good adhesion to the road. Furthermore, a detailed knowledge of air pressure distribution round a car is most useful, so far as the design of engine and brake cooling arrangements and ventilation systems are concerned.

There are many aspects of aerodynamic design, the significance of which are not fully appreciated. One is that if the shape of a body is such that it generates lift as it moves forward through the air, not only is the adhesion between the wheels and the road reduced, but also the drag is unnecessarily increased. This latter feature is introduced because the resultant of the lift forces is inclined backwards and therefore has an appreciable rearward component. Moreover, since the magnitude of the lift increases as the square of the speed, the loss of road adhesion becomes really serious at high speeds, when the demands with regard to the transmission of controlling forces between the tyres and the road are greatest. Both these undesirable features can be obviated by relatively simple measures to reduce the effective camber of the body profile, as viewed from the side. The way in which this can be done will be discussed in an article in next month's issue of *Automobile Engineer*.

For the family saloon as well as sports and racing cars, stability in side winds is, perhaps, even more important than drag reduction. Sudden exposure to a strong gust of wind from the side can alter the line of travel of the vehicle in a relatively short distance to such an extent as to displace it a foot or more from the course intended by the driver. To what extent this is responsible for road accidents is difficult to determine, since in such emergencies the driver inevitably is so intent on trying to avoid the catastrophe that he is not likely to analyse accurately the causes; and, after the event, in his disturbed state of mind, he probably would not remember exactly what had caused him to be off course. In any case, he would find it very difficult to convince anyone in a court of law that the wind blew his vehicle into the other car.

Since stability and accurate handling characteristics are of vital importance in high-speed sports and racing cars, it is mainly in respect of this type of vehicle that practical application has been found for the fundamental theories of car aerodynamics. Even so, these fundamental principles are not yet widely understood. For example, there are few who realize that a single stabilizing fin in the turbulent wake behind an open cockpit is relatively ineffective, and that vastly better results can be obtained with two, one on each side, in the undisturbed air stream.

Recently, outwardly-flared fins have been used, and have generally been regarded simply as a passing fashion, conjured up by the stylist. This fin arrangement, however, can be justified on the basis of sound aerodynamic principles. In the first place, it helps to place the fins outside the turbulent wake behind the cockpit or canopy, and secondly, on account of the large lateral component of the airflow at the rear of the car, this layout is more effective than the more common vertical fin arrangement.

Aerodynamic principles can also be studied to advantage in relation to internal flow systems in the vehicle. For example, there is a strong case for placing engine cooling air discharge ducts on the sides of the vehicle, rather than on top or below. Improvements that can be effected with regard to internal ducting arrangements were described in an article entitled "Cooling Air Flow" in the January 1956 issue of *Automobile Engineer*. It is possible that by attention to all these features economies could be effected in respect of power absorption by the cooling system.

The open cockpits of racing and sports cars are generally in areas of low pressure. This means that all internal air circulations tend to be directed into the cockpit. As a result the driver may be hampered by inflowing dust, which may get in his eyes, and by fumes, which may be toxic. Moreover, if the car should catch fire, he is liable to be immediately enveloped in flames drawn into the cockpit by the airflow. This is an aspect that merits careful study by those who formulate rules for sports and racing events.

Airide Springs

Some Comments on Firestone Springs Under Development for Cars and Commercial Vehicles

BOTH the double- and single-convolution types of pneumatic spring are undergoing development by The Firestone Tyre and Rubber Co. Ltd., of Brentford, Middlesex. Much of the work that they have so far completed in the field of air suspension has already been described in a paper by J. H. Sainsbury[1] of that company, so this article will be confined to some comments on the springs only. Information on the theory of air suspension can also be found in two articles that have been published in *Automobile Engineer*[2],[3] one in *ATZ*[4], and another in *ETR*[5].

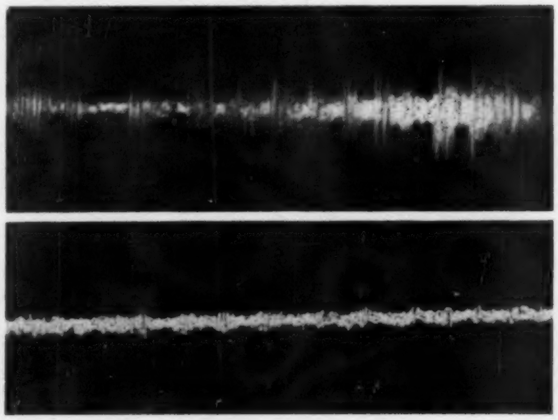
Double-convolution type

The double-convolution type springs manufactured by Firestone comprise a rubber and fabric moulding, round the centre of which is a steel girdle to limit radial deformation, and at each end, a steel retainer ring, together with special bolts, to seal the bellows against their seatings on the sprung and unsprung parts of the suspension assembly. Standard bolts cannot be used, because the heads have to be shaped to conform with the profile of the retainer ring, otherwise they would damage the rubber beads and walls.

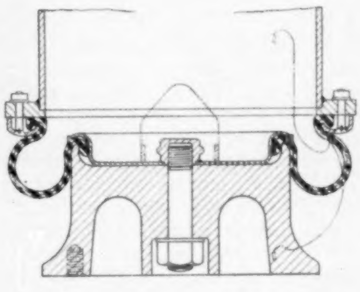
The end-faces of the beads are grooved to increase the effectiveness with which they seal against their seatings. There are two reasons why the grooved surface is more efficient in sealing than a plain surface. One is that the grooves reduce the bearing area between the bead and its seating, and therefore increase the bearing pressure for a given axial load. The other is that they act in a manner similar to a labyrinth seal in that, if any leakage takes place, there tends to be a pressure gradient across the series of grooves. Thus, the pressure differential between one groove and the next is considerably lower than that which exists between the inside and outside of the bellows; in fact, it is much lower than the sealing pressure between the rubber lands and the steel seating face, so further leakage is unlikely to occur.

Air springs are generally designed so that when the vehicle is fully laden, the pressure in the static condition is in the order of 60—70 lb/in². One reason for this is that existing pneumatic brake systems operate at pressures of about 80 lb/in², so the same source of air pressure can be used and there is adequate reserve of pressure to cater for overloads. The springs can, however, be operated at higher pressures if vehicle manufacturers wish to do so. It is recommended that a pressure of 100 lb/in² should not be exceeded; this gives a factor of safety of 5:1, so far as bursting is concerned. With the double-convolution types of springs, the ends of which are bolted down, there is not any specified minimum pressure; in fact, satisfactory performance has been obtained with pressures as low as 2 lb/in².

Accelerometer traces, showing how much better the ride obtained with air springs is than that experienced with conventional, semi-elliptic springs. The lower trace is that obtained with the Airide springs substituted for steel springs in a trailer currently in production



Cross section of an Airide single-convolution type spring. The inner bead of the rubber component is bonded to the flanged centre plate



Because the maximum practicable virtual deflection obtainable with this type of spring is limited, owing to surge tank volume requirements, the minimum attainable frequency is approximately 80 c/min. This would appear to limit its application to commercial vehicles and trailers, but possibly excluding those used for passenger transport. The advantages of air suspension for these applications are so well known that there is no object in repeating them here. However, the accompanying reproductions of accelerometer traces are new and interesting evidence of the improved ride characteristics obtained with a trailer equipped with air suspension, as compared with one with conventional steel springs of semi-elliptic form.

Single-convolution type

For private cars and for passenger-carrying public service vehicles, the Firestone, single-convolution air spring has much to commend it. As can be seen from the accompanying illustration of the cross section of this type of spring, the fabric-reinforced rubber component is of annular form with beads on its inner and outer peripheries. The outer bead seats on a flange round the rim of an inverted, cupped pressing that forms the air container, or cylinder. It is secured to this flange, by a steel sealing ring and a set of special bolts, in much the same way as the beads of the double-convolution type already described. The inner bead is bonded under a lipped flange round a circular dished plate. This lipped flange clamps the bead down on to the top rim of the pedestal. As the suspension deflects up and down, the pedestal acts as a piston, moving in and out of the cylinder formed by the cupped pressing above. The seal between the piston and cylinder is formed by the rubber bellows. A boss at the centre of the dished plate has a collar round it to register in

a groove in a bump-stop rubber that can be fitted over it, if required. Also, the boss is drilled from its lower end and tapped to receive the central stud, or set bolt, that pulls the plate down on to the pedestal.

With this type of air spring, frequencies of as low as 40 c/min can be obtained, because it is relatively easy to regulate the shape of the load deflection curve by employing pedestals of different forms. Another advantage of this type of air spring is that it can generally be used with a surge tank of relatively small volume. For this reason, the single-convolution type spring installation is more compact than that of the double-convolution type. It is this feature, as well as the low frequencies and relatively large deflections obtainable, that makes the single-convolution type spring particularly attractive for private cars and light commercial vehicles.

Relative merits

So far as performance is concerned, the relative merits of the two types of spring are shown in the accompanying illustrations comparing the characteristic curves for a single- and a double-convolution type spring, both designed for application to the same vehicle. From these curves, it can be seen that the variation in frequency, as between the laden and unladen conditions, is greater for the single-convolution type than for the double-convolution type. The figures are: 103—75 c/min for the single-convolution and 80—75 c/min for the double-convolution types. However, from the shape of the curves, it can be seen that, with the single-convolution type, the rate of build-up of load reaction as the spring approaches the bump condition is higher than with the double-convolution type spring, and that as the spring approaches the rebound condition, the rate of fall-off of pressure also is greater. This means that with the single-convolution type spring, impact loading on the chassis is reduced, since both the frequency and force with which the bump and rebound stops are struck are less.

The fact that the rate increases more rapidly at the ends of the stroke with the single-convolution type of spring can be explained mathematically as follows:

$$Rate = \frac{dL}{dx}$$

$$= \frac{d(PA)}{dx}$$

But $$\frac{d(PA)}{xd} = P\frac{dA}{dx} + A\frac{dP}{dx}$$

$$= P\frac{dA}{dx} + A\frac{dP}{dV}\frac{dV}{dx}$$

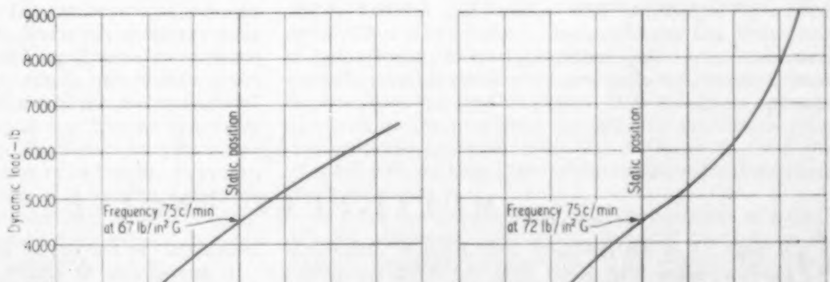
where L is the load, x the deflection, P the air pressure in the spring, A the effective plan-area of the spring, and V the volume enclosed by the spring.

Thus, it can be seen that under isothermal conditions, the rate of the spring depends on two variables. One is the rate of change of effective plan-area and the other is the rate of change of volume. As the double-convolution spring deflects, the rate of change in effective area is small by comparison with that experienced with the single-convolution type spring, in which the variation in area is, of course, obtained by virtue of the shape of the pedestal over which the bellows seats. For the same reason, the term dV/dx also varies more widely with the single convolution type of spring than with the double-convolution type. This is primarily due to the fact that a relatively small surge tank is employed with the single-convolution type.

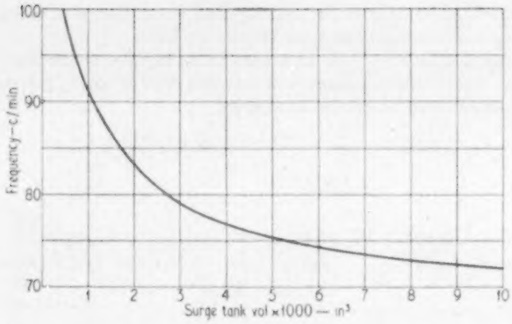
With the double-convolution type spring, the factor dA/dx, in the first term of the equation, could be made to have a greater influence at the bump end of the stroke if the end cheeks of the bellows were designed to come up against the seatings towards that end of the stroke. However, this is not generally considered to be desirable, because of the likelihood that mud and stones would be trapped between the cheeks and the seatings and damage the bellows. This trouble could, of course, be obviated by the employment of gaiters, but the additional cost of such an arrangement could hardly be justified.

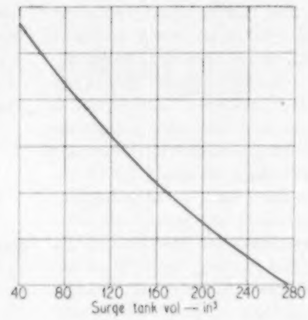
Other interesting features of the two springs, the curves of which are illustrated, are as follows. Although the double-convolution bellows gives a maximum deflection of 8 in and the single-convolution type designed for the same application gives a maximum deflection of 7½ in, the overall height of the double-convolution type is approximately twice that of the

Above: Double- and single-convolution type springs designed for a common application. The height of the single-convolution type spring is approximately half that of the other spring, which is on the left



Right: Of these two sets of curves, that on the left shows the characteristics of the double-convolution type spring illustrated above, while that on the right shows those of the single-convolution type. Both were designed for the same application, but that on the left required a surge tank volume of 5,300 in³, while the other required only 200 in³





Two curves showing the relationship between natural frequency and surge tank volume for the units illustrated on the previous page. That on the left is for the double-convolution type spring, while the other is for the single-convolution type. Both were tested under a load of 4,480 lb

single-convolution type. This can be seen easily from the accompanying half-tone illustration. Another difference between the two is that the surge tank volumes are 5,300 in^3 and 220 in^3 respectively for the double-convolution and the single-convolution types. That such a small surge tank is practicable with the latter type makes it particularly well suited to private cars and other applications where the space available is strictly limited. The reason why the tank can be made so small is that $P(dA/dx)$ is by far the more important of the two terms in the expression for the rate of the single-convolution type. An accompanying pair of curves shows how frequency varies with surge tank volume for these two springs, which were designed for a load of 4,480 lb.

In general, single-convolution type springs have to be operated at higher pressures than the double-convolution type. This is because the air pressure in the spring must be sufficient to force the diaphragm down evenly on to the flanks of the pedestal as the suspension moves up to full bump. If this pressure is not high enough, the diaphragm is liable to wrinkle as it seats round the pedestal. This causes heat to be generated and there is consequently a danger of rapid deterioration of the rubber. On cars, the lowest practicable pressure is approximately 40 lb/in^2, while for public service vehicles, the minimum pressure would be less according to the diameter of the outer bead. With this type of spring, the maximum practicable ratio of laden to unladen weight is approximately 4:1.

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ACCIDENT CASUALTIES

WHEN the term accident casualties is mentioned, the general public seem frequently to assume that it refers only to pedestrians who have been struck by cars. However, an impact, even with the car travelling at 25 m.p.h., can cause an occupant to strike the interior of the vehicle with the same force as a pedestrian being struck by a car at the same speed. The fact of the matter is, that it is not just high speed that kills: any speed can kill.

The University of California has recently produced a film that summarizes seven years of research and experiment on automobile collisions. Throughout all these years, the science of impact has been under close scrutiny at the University, and their film points out some new and hitherto unknown facts. Stop-action, high-speed photography is used to provide a clear insight into the injury-producing agencies associated with collision. Two new cars, one of unitary and the other of conventional frame construction are specially instrumented to record engineering and medical data during impact. High-speed cameras record in very slow motion, from several angles within and outside the cars, the severe crushing and extreme collapsing of these car structures. The effect on life-like anthropometric dummy occupants of these vehicles is shown. Engineering and medical post-collision analyses are described, together with some of the more general findings resulting from these experiments. One form of car occupant protection discussed is seat belts. This 16 mm film, which runs for 12 min, is not only an educational aid for anyone who drives, but also is of interest to designers. Further information concerning it can be obtained from The Education Film Sales Department, University Extension, University of California, Los Angeles 24, California, United States of America.

MULTI-FUEL ENGINES

ON page 53 of the February 1958 issue of *Automobile Engineer*, some brief notes were published concerning the Mercedes-Benz multi-fuel engines. It was stated that, "Among the kinds of fuel usually employed are: normal petrols, super petrols, military grades of fuel, and petrol-benzol mixtures; these fuels cannot, however, be used for starting." This statement requires clarification. Although difficulty has been experienced in the past with the starting of multi-fuel engines when operating on highly aromatic (45-55 per cent) fuels, this difficulty has now been completely eliminated by the use of glow plugs of a special design.

It should also be emphasized that normal petrol, super petrol, and the various military grades of fuel do not, of course, fall under the classification of highly aromatic fuels. Consequently, there has never been any difficulty when starting multi-fuel engines with them, nor has there been any restriction with regard to their use with these engines. Further details can be found in a Paper on the Mercedes-Benz multi-fuel engines, by Dipl. Ing. Heinz Hoffmann, which was published in the October 1957 issue of *MTZ.*

ALUMINIUM ALLOY BEARINGS

History of the Development of Reticular Aluminium-Tin Steel Backed Plain Bearings

FOR some years, aluminium alloys have been used for crankshaft and big end bearings. In England considerable experience has been gained in the use of bearings of aluminium alloyed with 5-7 per cent tin, without steel backings, in diesel and petrol engines. These alloys, which were introduced in about 1936, initially showed great promise in that their frictional and wear characteristics appeared to be considerably better than those obtained with any previously used aluminium alloys. Indeed, in some cases they were used on soft shafts, seemingly without trouble. They were adopted by one or two important manufacturers of diesel engines who used them fairly extensively. Gradually, however, troubles began to develop. Occasionally there were seizures of a very serious nature, resulting in considerable damage to the engine. Experience also showed that the yield strength of these alloys was insufficient to enable bearings to maintain an adequate interference fit in main bearing housings and connecting rods. There were cases of dowel holes gradually being elongated until location of the bearing was lost to such a degree that oil feed holes were throttled. One manufacturer, who had used these bearings extensively, had to replace all of them with a different type.

Extensive experience showed that this aluminium alloy containing 5-7 per cent tin was not satisfactory as a compromise between the two opposing requirements. These requirements are: low wear characteristics, which call for additions of tin or other low melting point metal; and higher strength, which can only be achieved by reducing the tin content. It became clear that one solution might well be along the lines of a considerable increase of tin content, to improve the anti-scuffing characteristics, and the bonding of this high tin alloy to a steel backing to increase the strength of the bearing.

A great deal of work has been done in the United States with steel backed aluminium alloy bearings, and these have been used extensively for many years by one very large firm of diesel engine manufacturers. The alloy employed contains 6 per cent tin; however, success has only been achieved at the expense of hardening the crankshafts and by the maintenance of unusually rigid discipline with regard to limits, finish, cleanliness of the engine, etc. Even with such an approach, many diesel engine manufacturers have been unable to obtain satisfactory results in the use of alloys of this nature. One manufacturer in the United States has produced steel backed bearings lined with an aluminium alloy containing a small percentage of cadmium. However, this alloy is not wholly satisfactory as a bearing surface, so it is generally given an electro-deposited lead-tin overlay. In these circumstances, the aluminium alloy is not the bearing surface, but merely an interlayer.

So far as the history of aluminium bearings in other parts of the world is concerned, the trends already outlined were also experienced by more or less independent operators in England and in Germany, as well as in the United States of America. E. W. Hives and F. Llewellyn-Smith in the *S.A.E. Journal* of December 1940 stated that Rolls-Royce car and aircraft engine big end bearings were of aluminium-based alloys containing 5-7 per cent tin, but lead-bronze was employed in the Rolls-Royce Merlin engines; the use of aluminium alloyed with 5-7 per cent tin for bearings was substantially limited to a car engine. The Rolls-Royce patent No. 426211, dated the 29th March, 1935, included a range of tin content from 8-19 per cent, but it is known that as-cast alloys containing over 10 per cent of tin are weak because the aluminium phase is discontinuous. Moreover, owing to the very rapid formation of brittle aluminium-iron compounds, the casting of the aluminium-tin alloy on to steel is not suitable for the manufacture of these bearings.

In the United States, Hunsicker, of the Aluminium Company of America, said that it was evident from extensive research that 20-30 per cent of tin was desirable in the aluminium, in order to obtain adequate anti-scuffing properties with cast alloys, but that the mechanical requirements of most bearings placed an upper limit of about 10 per cent on the tin content of such alloys. As a result of the research, a series of well known alloys of high fatigue strength was developed, but these alloys were highly sensitive to dirt in the oil. The report on this work, entitled "Aluminium Alloy Bearings—Metallurgy, Design and Service Characteristics", was published in the *Journal of the American Society of Metals*, 1949.

From 1932 to 1943, development work with various tin-free or low-tin content aluminium-based alloys was carried out in Germany by the Karl Schmidt Company. In a report by Dr. Ing. Carl Englisch, experience similar to that of Hunsicker is described. Bench tests gave satisfactory and encouraging results, but road tests sooner or later showed failure by gross scuffing and seizure. These tests also indicated that these bearings were excessively sensitive to external influences and that their successful use, in any case, would depend on a high standard of lubrication. This report is available as one of the Document Reprints of the Air Documents Division of Headquarters of Air Materiel Command, Wright Field, Dayton, Ohio. The reference number is MX1191 U.S. Army Air Force Card Index (German Technology ADRC).

Steel backed, high tin content, aluminium alloy bearings

It can be seen that two problems had to be solved before the full advantages of aluminium-tin alloys could be obtained. The first was the production of a high-tin aluminium alloy in which, to get maximum strength, the aluminium phase was continuous. Secondly, it was necessary to bond this alloy to a steel backing, without forming excessive aluminium-iron compound.

Of these two problems, the first was overcome as a result of work, sponsored by The Tin Research Institute, at the Fulmer Research Laboratories. The second was solved jointly by The Tin Research Institute and The Glacier Metal Co. Ltd.; this was done some three years ago. During 1956, Glacier developed from a pilot plant a small production plant for making composite aluminium-tin-on-steel strip. This plant has been operating continuously for the last eighteen months. It is capable of making bi-metallic strip up to 0·1 in thick, that is, a thickness adequate for the bearings of most engines developing up to about 200 b.h.p. A

TABLE I CHARACTERISTICS OF VARIOUS BEARING MATERIALS

Material	Running conditions: Hydrodynamic	Boundary	Break-down	Environment	Remarks
	1. Strength to withstand load. The ratio of fatigue strength relative to tin-base white metal, 0·015 in to 0·020 in thick, is shown in brackets 2. Softness to initiate and maintain oil film	1. Surface wettable by oil 2. Chemical affinity for molecular layer of oily radical constituents	1. Surface to have a low melting point phase 2. The low melting point phase not to work-harden and to be softer than the matrix 3. Effect of 2-minute oil supply failure	1. Bearing metal constituents must not be prone to grain boundary penetration in steel at their melting points 2. Must not cause catalytic breakdown of oil 3. Must resist corrosion	
Tin-based and lead-based white metals	1. Usefulness limited unless bonded in a very thin layer to steel (Unity) 2. Very good	1. Good 2. Tin-base white metal fair; lead-base white metal good	1. The whole alloy has a low melting point 2. The matrix has a lower melting point and is softer than the discontinuous phases 3. Surface wipes and lining runs	1. Good 2. Good 3. Tin-base white metal good; Lead-base white metal fair	The main defect of white metal is its inadequate strength for many modern applications
Copper-lead	1. Good when bonded to steel (1·7 for copper-lead 70/30) 2. Poor to fair according to lead content	1. Good 2. Fair	1. Good 2. Good 3. Very high surface temperatures develop	1. Poor 2. Poor 3. Poor	Copper-lead is a good bearing material, by and large, but it is a little too hard for use universally with soft crankshafts, and is susceptible to failure in certain environments, for example, severe edge loading
Copper-lead with overlay of lead-based alloy	1. Good when bonded to steel (1·5 to 2·0, depending on thinness of overlay) 2. Good	1. Good 2. Good	1. The whole of the surface alloy has a low melting point 2. The matrix has a lower melting point and is softer than the discontinuous phases 3. Overlay wipes	1. Good so long as overlay lasts 2. Ditto 3. Good in the presence of corrosion inhibitors, such as tin or indium, in the lead	If there is cavitation in the oil film, overlays occasionally wear or fatigue and leave a bare copper-lead surface with poor accommodation in many environments
Aluminium-silicon	1. Good (2·0 to 3·0 +)* 2. Fair	1. Good 2. Good	1. Poor 2. Poor 3. Is likely to seize	1. Good 2. Good 3. Good	Aluminium-silicon is a good bearing material, except for its deficiencies in properties required for break-down conditions of operation. It is usually provided with a tin- or lead-based overlay
Aluminium 6-9 per cent tin	1. Good when bonded to steel (2·0 to 3·0 +)* 2. Fair	1. Good 2. Good	1. Fair; the amount of the low melting point phase is marginal 2. Fair 3. Is likely to seize	1. Good 2. Good 3. Good	The aluminium 6-9 per cent tin alloys are reasonably good, but the conditions of assembly and the standard of machining of both the journal and bearing surfaces have to be very good in order to overcome the defect of inadequate low melting point phase. For this reason they are probably unsuitable for large engines
Aluminium 20 per cent tin, reticular structure	1. Good when bonded to steel (2·0 to 2·5 +)* 2. Good	1. Good 2. Good	1. Good 2. Good 3. Moderate surface temperatures but no seizure or serious change in dimension	1. Good 2. Good 3. Good	Reticular aluminium 20 per cent tin can operate at much higher loads than white metal on a soft shaft, without the degree of journal wear that is experienced when copper-lead is used. Reticular aluminium 20 per cent tin also operates at surface temperatures that would cause white metal bearings to wipe, or would remove the overlay of plated copper-lead bearings

**The upper limits of fatigue strength of the three aluminium alloys referred to have not yet been established. The figures relate to values obtained to date*

TABLE II. COMPARATIVE FATIGUE STRENGTH AND WEAR DATA OF VARIOUS BEARING MATERIALS

Aspect	Reticular aluminium-tin on steel	Other current bearing materials
Fatigue: Reference conditions: Average surface temperature 100 deg C Shaft slope approximately 0·15 per cent Peak load 3,000 lb/in² Lining thickness 0·015-0·020 in	Permissible stress at 100 deg C is 4,600 lb/in² on projected area. The effect of rise of temperature is low compared with its effect on white metal. At 150 deg C the fatigue strength is at least 3,500 lb/in²	White metal: Permissible stress 2,000 lb/in² at 100 deg C, falling to about 1,500 lb/in² at 150 deg C 70/30 copper-lead: 3,500 lb/in² falling to about 3,000 lb/in² at 150 deg C
Maximum lining thickness 0·007 in	Reduction of the thickness of the lining increases fatigue strength, but not so sharply as with low melting point alloys. At 0·007 in thick, the fatigue strength is over 5,000 lb/in² under reference conditions. Thinner linings have not yet been assessed	Reduction of thickness of lining to 0·007 in increases fatigue strength of white metal to about 2,400 lb/in²; at 0·004 in, the fatigue strength is about 3,000 lb/in² Fatigue strength of 70/30 copper-lead is also increased by reduction of thickness and is about 4,000 lb/in² at 0·007 in. Thinner linings have not been assessed
Wear: The data are in terms of journal wear, expressed relative to operation with tin-base white metal	1·6 times that experienced on shaft running on white metal*	70/30 copper-lead: 2·3 times that obtained with white metal Copper-lead, with 90 per cent lead and 10 per cent tin overlay not less than 0·001 in thick: 0·9 times that with white metal Aluminium-6 per cent tin-1 per cent copper-1 per cent nickel: 2·2 times that with white metal
Material compatibility: Resistance to seizure or interpenetration with journal material if oil supply fails	Aluminium will not penetrate intercrystalline boundaries of steel because its melting point, 660 deg C, is less than the critical change temperature, of 768 deg C, for steel. The high tin content, 20 per cent, of reticular aluminium-tin alleviates the conditions where local surface damage is initiated in the event of oil failure	Copper, at its melting point of 1,083 deg C, penetrates the intercrystalline boundaries of steel in fractions of a second. This can cause crankshaft failure The lead in copper-lead alleviates the conditions at local surface damage areas, but cannot in the long run prevent copper penetration; nor can a lead-tin overlay do so

**These figures are based on tests in motor vehicles with shafts of hardness averaging about 200 B.H.N. In more than 100 engine tests, it has been shown that the wear that takes place in the first 300 miles accounts for more than half the total wear in 3,000 miles. This is because the detritus produced in the engine and permitted to come down from the combustion chambers past the piston rings in the first 300 miles is very much larger in size than thereafter, when the controlling surfaces have been run in. With soft shafts, typical wear figures in long stroke engines are in the order of 0·0005 in after 1,000 miles; 0·0008 in after 11,000 miles and 0·0012 in after 33,000 miles. In engines where the bore: stroke ratio approaches or exceeds unity, the wear rates are very much less than those quoted, and are in the order of 0·0001 in per 10,000 miles after the first 1,000 miles. With hardened shafts, the rates of wear are almost negligible, except in the most severe environments, such as with earthmoving equipment without adequate control of dust entry to the engine*

major production plant, having a capacity to make bi-metallic strip up to 0·2 in thick is in operation, so material is also available for the manufacture of bearings for large diesel engines designed for a wide range of different applications.

Conditions of operation

The conditions of operation of journals in lubricated bearings may be classified as follows:

1. Hydrodynamic—where oil is available at the entry to the converging region of the clearance space
2. Hydrostatic—where oil is supplied at pressures exceeding the specific load on the bearing in the appropriate region
3. Boundary—where the journal and bearing metal surfaces are separated by very thin films of oil, which are attached chemically to the journal and/or bearing metal or oxide surfaces.
4. Break-down—where the journal and bearing metal surfaces are in contact.

As regards hydrodynamic and hydrostatic conditions, the only property required of the bearing metal is strength to withstand the applied loads. That is, once the hydrodynamic film between the journal and the bearing is established, the surface properties of the journal and bearing metals are immaterial. Softness of the metal, however, aids the formation of hydrodynamic films, as do to a lesser extent certain other surface properties.

It is with regard to boundary and break-down conditions that the surface properties of journal and bearing metals become of paramount importance and, as practically all journals and bearings have to operate at some time or other under these conditions, the metals must be appropriately chosen with regard to their compatibility in these circumstances.

To operate under boundary conditions, the metal surfaces must be more than merely wetted by the lubricant: at least one of the surfaces must bond chemically to oily radical constituents in the lubricant, to form a molecular layer; moreover, should the layer be damaged as a result of metal-to-metal contact, it must be capable of being healed automatically. On evidence at present available, bearing alloys with a high free energy of oxide formation are more likely to be better in this respect than those that have a low free energy of oxide formation. Since the journal is usually of steel, the requisite properties must generally be inherent in the bearing alloy.

Operation under break-down conditions is essentially of very short duration and inevitably modifies at least one of the sliding surfaces. The modification to one of the surfaces during breakdown conditions must be such as rapidly to alter the conditions so as to prevent significant damage to either of the two surfaces involved. Bowden has shown that when two metals are in sliding contact, the temperature reached is the melting point of the phase having the lowest melting point, and if this is substantially lower in one of the surfaces than in the other, the effect for short periods is immediately to relieve high local specific loads and to

prevent gross damage. Since the temperatures of sliding contact are so high, the metal constituents of the bearing alloy should not be prone to penetration of the journal material.

Bowden has also demonstrated that in the case of a multiphase material where one of the phases is fairly soft and has a relatively low melting point, the coefficient of friction is low and the effect in metal-to-metal sliding contact is to inhibit the occurrence of further damage. Hence, two-phase materials, in which one of the phases is soft and of low melting point, are advantageous as bearing surfaces.

Comparison with other bearing alloys

Since no material yet discovered is perfect in all respects, a compromise is unavoidable. Reticular aluminium-tin on a steel backing has a high fatigue strength and has relatively good anti-scuffing properties, as compared with other known bearing metals of high fatigue strength.

The conventional white metal bearing alloys are not strong enough to meet many present-day requirements, and the most commonly used alternative is copper-lead. This is a two-phase material, but has a number of disadvantages. First, the copper phase has a high melting point and is rather hard. This leads to a high rate of journal wear, unless the journals are hardened. Unfortunately, the hardening process is usually expensive. Secondly, copper penetrates steel very rapidly and can cause shaft embrittlement, and there is a possibility of shaft breakage if any substantial or prolonged metal-to-metal contact occurs. The third defect is that, with certain modern oils, copper-lead is susceptible to corrosion, especially in engines where high sulphur content fuels are used. Copper also acts as a catalyst in the break-down of certain constituents of modern high-duty oils.

Table I summarizes the relative merits of conventional bearing alloys or composites, and some aluminium alloys, including reticular aluminium-20 per cent tin. Table II gives the comparative fatigue strength and wear data of the various materials.

The use of three-layer bearings, in their necessarily prefinished condition, for mass produced small diesel engines is a practice that is now well within the compass of modern technology. For large diesel engines, this still represents serious difficulties when the number of engines of a particular type produced is small. Aluminium-tin bearings, on the other hand, are capable of being bored in position in the engine, and this practice enables the necessary degree of accuracy on assembly to be more easily obtained. Plants now being built will enable bearings of aluminium-tin on steel to be produced at lower cost than the three-layer bearings. This reduction in cost is possible because of the lower cost of the alloys used, the elimination of overlay plating, and the speedy and controllable nature of the process used in the production of aluminium-tin bearings.

Although bearings of reticular aluminium, alloyed with 20 per cent tin, and steel backed, are relatively new, they have been applied successfully as original equipment to a wide variety of engines produced in both small and large quantities. Thus, the experimental results have been confirmed by the fact that hundreds of thousands of engine bearings made by The Glacier Metal Company Ltd. are operating satisfactorily in service not only in Great Britain but also abroad.

PLASTICS FOAM

FOAMOPRENE is the trade name of a plastics foam made from the polyurethane group of resins. It is similar in appearance to fine foam rubber, but is one of the lightest materials available. Since it is resistant to chemical action with the materials with which it is likely to be brought into contact, it is said to last almost indefinitely.

Because of these properties, the material is well suited for use in upholstery of all kinds. However, its light weight makes it particularly suitable for use as a vehicle trim material. It is available in sheet form, which can be cut easily to produce padding for components such as arm-rests and cushions. Alternatively, it can be supplied ready made up to a specific design.

The material can be produced in profiled form. Cavities formed on its under-side reduce the weight and consequently, cost; the shape of these cavities is designed to give the required degree of softness and comfort. It is claimed that Foamoprene has a greater rigidity than foam rubber, and thus the support it offers is improved, while at the same time the cushion is not noticeably harder than those made of rubber.

Reversible cushions made of profiled Foamoprene have recently been introduced. They can be produced in shapes and sizes to meet any requirements. It is claimed that they are the least expensive form of foam cushioning available. A cushion measuring 18 in square by 4 in deep weighs only 20 oz; it is stated that this extreme lightness of weight in no way affects the ability of the material to stand up to hard wear. Foamoprene can be used for applications other than upholstery: it has thermal insulation properties and also can be used for soundproofing.

It is available in the natural white colour, or in pink, green, yellow, blue, grey or brown. These colours are water-fast. It can be produced in thicknesses ranging from $\frac{1}{16}$ in to 1 ft, and in widths up to 3 ft. Normally, it is supplied in lengths of 18 ft, although this can be exceeded in special cases. Its specific gravity ranges between 0·028 and 0·055, according to whether it is supplied in the Super-Light, Light, Medium or Heavy densities.

The material is unaffected by water, air, petrol, grease, detergents, and disinfectants. It will also resist weak acids and alkalis, and most solvents. Dry heat over long periods does not affect it, and the material can be boiled and subjected to steam for shorter periods. It does not support bacterial growth.

Foamoprene can be cut with scissors, knife or band knife. It can be punched, drilled, stitched, stapled or stamped, and can be buffed to almost any shape. For finishing, it can be screen printed, sprayed, electrostatically flocked or heat embossed. The material can also be rendered flame-proof and can be produced in specially heat-resistant form. In addition, it can be combined with other materials, and can be supplied with an adhesive coating on one or both faces. Further details can be obtained from the manufacturers, who are Kay Brothers Plastics, of Marple, Stockport.

INDEX AND BINDING

The index to AUTOMOBILE ENGINEER, *Volume XLVII, January to December, 1957, is now available, price 6d, or by post 8d. Binding cases and index can be supplied separately, price 7s 6d, or by post 9s. Remittance should be sent to Dorset House, Stamford Street, London, S.E.1.*

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Car Aerodynamics

Part I: A Review of Current Knowledge, and an Introduction to the Research Work Carried Out at Auckland University, School of Engineering

G. E. Lind Walker, M.A., A.F.R.Ae.S., Assoc.I.Mech.E., A.M.N.Z.I.E.

EVEN as early as 1899, when Camille Jenatzy in his slim, streamlined, electric car raised the World Land Speed Record to 65·79 m.p.h., there was already in existence a record of wind tunnel tests on a model railway train, although at that date there does not appear to have been any aerodynamic work specifically applied to the motor car. In 1910, a Gregoire aerodynamically-designed car appeared on the road, and this was followed in 1911 by Oscar Bergmann's proposed design of an airship-shape car, with a smooth undersurface and enclosed wheels. The all-enclosed, beetle-backed form of saloon appears to have been generally accepted by about 1913. Since then, there has probably been little further progress in the reduction of the resistance of the car body, though better understanding of the whole problem has led to detail refinements that have reduced considerably the parasite losses.

Since 1899, many works recording aerodynamic investigations on motor cars and other land vehicles have been published. However, it is regrettable that over these years there may have been an even greater number of works that were never published. In particular, these unpublished works probably include tests on models of speed record contenders. Early investigators treated the problem as if it concerned purely one-dimensional resistance, as is exemplified by Zeder[1]. The airflow pattern shown in Fig. 1 demonstrates the invalidity of this assumption. In this illustration, the streamlines are seen to flow over the centre of the car, down to ground level, outwards and then upwards, to curl in the form of trailing vortices; there are even some signs of a lateral component over the roof of the car. Large lateral components in the flow were also characteristic of the model tested in the wind tunnel at the Auckland University; in this case, exploration was made with wool tufts, which showed a large component of flow outwards from an area close to the longitudinal centre-line, above the nose, and a corresponding large inflow beneath the tail.

Imaginative streamlined cars have been created at intervals, but have not attained popularity. Possibly the design of many of these machines has not been supported by adequate wind tunnel investigation. Further, it seems likely that important practical design features have been subordinated to aerodynamic considerations, resulting in an unbalanced overall design.

In 1928, Sir Malcolm Campbell's Bluebird appeared fitted with a stabilizing fin. This is an early example of thought on the influence of aerodynamic factors upon the directional stability of the car. Two years later, Irving[2] prescribed the basic requirement for aerodynamic directional stability as being the location of the centre of pressure a short distance aft of the centre of gravity. On the Golden Arrow, which was reported to handle well, this distance was less than 2 inches.

In 1933, Railton[3] directed attention towards the probability that aerodynamic factors contribute to the directional instability of some touring cars. At the same time, he described the regular technique for the construction of a streamlined body around a given mechanism. Four years after, Heald[4] went on to make a general investigation of the lateral forces due to side winds, and of the size of stabilizing fin or fins required for a typical saloon car—he actually fitted triple fins in order to reduce their individual size. Heald made records of the lifting forces on his models, although he did not attribute any practical significance to these forces. Investigations into the relative merits of different arrangements for simulating the road beneath a model in the wind tunnel were also produced at about this time.

The bulk of useful literature now available originates from the Motor Vehicle Research Institute of the Technical University at Stuttgart. Launched by government finance in about 1935, the Institute is still in operation; its Aerodynamics Section maintains, in addition to small tunnels, one wind tunnel large enough to accommodate a full scale car. The classic exploration of the whole subject of aerodynamic experimental technique by Schmid[5] was the first

Fig. 1. The airflow pattern is indicated by the dust in the air passing over this car. A single stream, passing over the roof of the vehicle, sweeps down to the level of the road and then divides by curling outwards. This division of the stream forms a series of trailing vortices, the distance between the centres of which is equal to the full width of the body of the vehicle

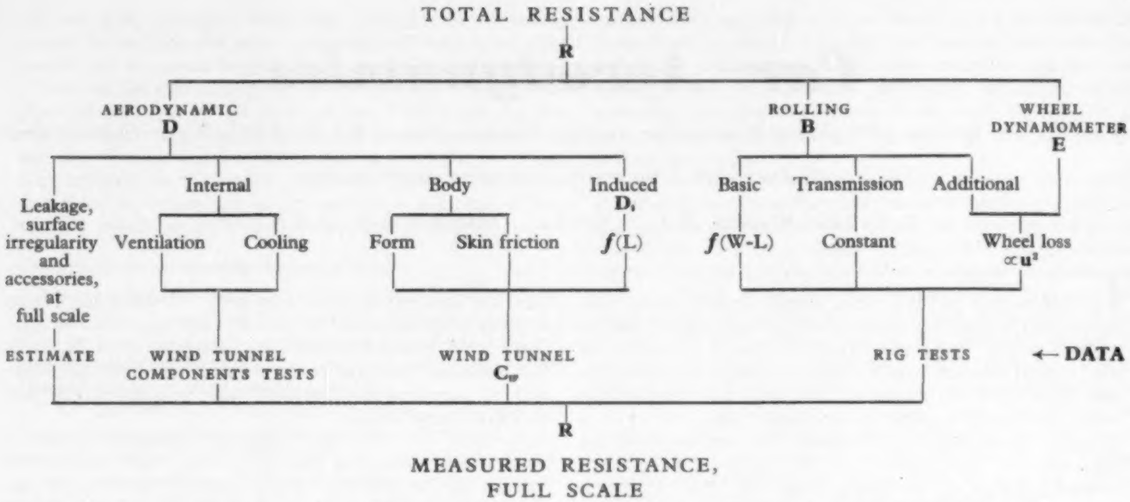


Fig. 2. This illustrates the relationship between the three main components of the total resistance which vary as the square of the velocity

of their major works to be published. The twenty years since then have seen the appearance of a series of works treating in detail various aspects of automobile aerodynamics. Koenig-Fachsenfeldt[6] has drawn freely upon all these works in the composition of his book.

From France, in 1947, came Romani's careful investigation[7] into the effect of scale in wind tunnel tests of motor cars. He confirmed the general observation that the resistance coefficient is independent of the scale, or Reynolds Number, but his tests showed that the two normal forces and their attendant moments vary considerably with scale; this is puzzling, as the constancy of resistance has been so universally observed that it is difficult to accept the idea of a general change of flow pattern with scale. In this connection, the investigation of the effects of degrees of undersurface roughness carried out at the AucklandUniversity, at Ardmore, New Zealand, might be regarded as a clue: it was found that the roughness in that area could produce quite large changes in lift and pitching moment for only moderate changes in resistance. Perhaps of more practical importance is Romani's emphasis of the significance of induced drag, from which it can be concluded that a body generating high lift can never have a very low resistance coefficient. This is because the resultant of the lift forces is not vertical, but is inclined backwards and therefore has a rearward component, termed the induced drag, which represents work done in lifting.

It is difficult to determine when interest was first shown in the lift and pitching moment components. Lift figures exist for the Golden Arrow; then, in 1938, record-breaking machines exhibited control difficulties that were attributed to front end lifting and, from that time, the published results of tests carried out at Stuttgart have generally included information on lift and pitching moments. It is also from Stuttgart that the bulk of the useful information now available concerning the directional effects of the side winds has come. Presentation of the results in terms of the six components of aerodynamic force, that is, forces resolved along three mutually perpendicular axes and the three corresponding moments, greatly extends the utility of the tests, since it then becomes possible to convert to other axes or origins, for application to a particular case.

Pressure plotting over the outside of the car, or model has been carried out from time to time. The information thus obtained is valuable for use when selecting locations for entries or exits for ventilation and cooling air. The current fashion of flush ventilation entries at the base of the windscreen is an example of useful application of pressure distribution knowledge.

The resistance of a car

Usefulness of streamlining can only be gauged in terms of the resistance of the car. The total resistance can be considered as the sum of four separate constituents:

1. Total aerodynamic drag, which can be estimated from wind tunnel measurements; this force varies with the square of the air speed.
2. Frictional or rolling resistance of the tyres, subdivided into basic resistance, which depends primarily on the load supported, and additional resistance, which is a dynamic loss varying with the square of the speed. At extremely high speeds it may become necessary to introduce a further factor, varying with a higher power of the speed, owing to vibratory energy in the tyre carcass.
3. Dynamometer loss at the wheels, which impart rotational energy to the air around them. This action is similar to that of the impeller of a centrifugal supercharger, the dissipated torque being proportional to the square of the peripheral velocity—in this case, the road speed.
4. Transmission loss, which is primarily due to the wheel bearings, and can be represented by a constant torque. It may also include gearing losses, which vary with engine power. The total should nevertheless remain relatively small.

These four constituents of resistance include three that vary with the square of the velocity, and thus are inseparable in a total measurement. The third and fourth items are often neglected, although in fact, at high speed, the dynamometer loss certainly becomes considerable. The inter-relationship of these factors is shown in Fig. 2. It can be seen that the induced drag is a function of the lift, which in turn decreases the load carried by the tyres and correspondingly the basic part of the rolling resistance. Estimates of the various contributory factors remain rather uncertain, so that *ab initio* estimates of the maximum speed of a particular vehicle are liable to have quite large aggregate errors.

A representative performance chart for a saloon car has been constructed in Fig. 3. Over the normal cruising range, which is well below maximum speed, the car has an ample reserve of power available for acceleration. Reduction of resistance cannot give any significant improvement in

performance over this range, although it will reduce the power required to maintain constant cruising speed. By careful streamlining, the total resistance over the cruising range might be reduced by as much as 30 per cent, with a corresponding reduction in the rate of fuel consumption at constant speed, provided that the transmission system is suitably matched to the requirements of the streamlined vehicle. With the original fixed gear ratios, the streamlined car might show no significant improvement in economy, because of the steady decrease of engine efficiency with decreased power at constant speed. Improved economy is obtained by operating the engine at a lower speed, at which the required power represents a greater fraction of the maximum available.

Test technique

Motor vehicles have their own peculiar difficulties with regard to the making of fundamental measurements. From a road test the value for the total resistance over a range of speeds can be obtained. However, subdivision of this value into the four basic constituents is more difficult, and may be impossible unless the sum obtained from estimates based on wind tunnel, tyre rolling and transmission rig tests comes very close to the measured total. Actual performance obtained is dependent on both resistance and available power. The power available may differ greatly from that measured with the engine on the test bed, owing to the different state of engine-driven accessories, the transmission losses and the combination of different working conditions, in particular under-bonnet air intake temperature. This whole group of uncertainties can be eliminated by the use of a chassis dynamometer.

The full-scale road investigation of aerodynamic factors is difficult. Induced drag can be measured. The remaining aerodynamic resistance might be determined by a pitot traverse of the wake behind the car, but this would be extremely laborious. There seems to be no practicable method of determining the side force; one reason for this is the virtual impossibility of operating a car on the road for any appreciable period at a known value of drift angle. Several methods can be used for the measurement of the lift, but they do not yet appear to have been employed on road tests. The aerodynamic moments certainly appear to be beyond reach at the present stage. Streamline flow pattern can be observed satisfactorily by several different methods, the pressure distributions over the surface can be recorded, and the internal flows measured and their losses evaluated.

A wind tunnel can be employed for the direct measurement of all six components of aerodynamic force, but there are problems in simulating the road passing beneath the car, and this could lead to errors in the final values obtained. If the model dimensions are such that it occupies more than 5-10 per cent of the cross sectional area of the working section of the tunnel, blockage by the model and its attendant fittings may modify the air flow pattern in the tunnel. This means that, to test a full-size car, a tunnel with a working section of about 20 ft diameter is required. In a smaller tunnel, a scale model must be used, or the effect of changes to a part only of the full-scale vehicle may be investigated. The cost of carrying out tunnel tests on a full-scale car is great; on the other hand, it is extremely difficult to represent detail features satisfactorily on a small-scale model. The value of small-scale model testing lies in the relative ease with which information can be obtained on which a design can be consolidated or a modification evaluated.

Deflections of the suspension may cause some variation of incidence, or angle of attack in the pitch, or θ, direction, but in the light of present knowledge, this appears to be so small that it may justifiably be ignored. Wind blowing from the side is, however, a common condition, so interest extends over a considerable range of values of the drift angle, τ, measured between resultant wind and the axis of the car. Fig. 4 shows that quite large values of τ may be experienced under extreme conditions, but that $\tau = 10$ deg is probably a representative working value.

Since road vehicles move in a direction practically along their own major axes, it is apparent that the resistance must also be effective along this line, and it can be conveniently so recorded. The normal components, lift and side force, are measured perpendicular to the major axis of the car. Fig. 5 shows the axes of reference used for presentation of reports on the series of tests that have been conducted at the Auckland University, Ardmore, and to which the other data in this work has been converted—at present there appears to be no universally accepted convention for these measurements. The origin of the system is usually the centroid of the wheelbase, at wheel centre height, although, for the tests conducted at Armore, a greater height was used.

This notation is consistent with the right-hand rule, each moment tending to increase in the magnitude of the relevant force vector; although in the particular cases of the drift angle τ and the side force S, the signs are opposite. A balance designed for measurement of the force components on a motor car in a wind tunnel would thus rotate complete with the model through the drift angle τ. In this respect, if differs from a balance for aeronautical work, which is fixed with its longitudinal axis parallel to the airstream, while the model is rotated to the required angles on the balance.

Representation of the road

The model has to be mounted near the axis of the wind tunnel, since the flow is not uniform close to the walls. In normal operation, of course, a real car is in close proximity to the road surface, and this influences the airflow pattern.

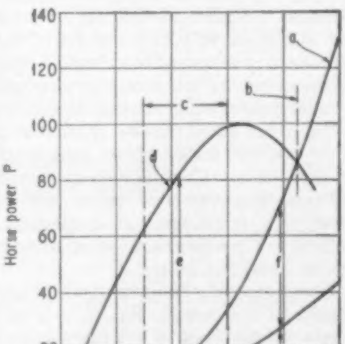
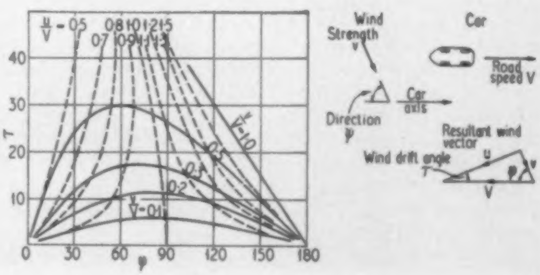
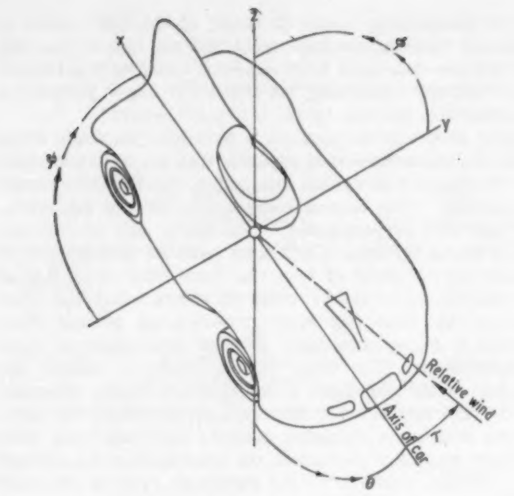


Fig. 3. Performance diagram of a typical saloon car, with a kerb weight of 25 cwt

a total resistance; b maximum speed; c cruising range; d power available; e power available for acceleration; f power absorbed by aerodynamic drag; g power absorbed by rolling resistance; h power absorbed by the transmission

Fig. 4. Below: Diagram showing how the drift angle varies with the angle of approach of the side wind, and with different relative velocities of the side wind and of the car





Forces				Moments					
Lift	**L**	direction	z	Roll	$M\phi$	about	x	direction	ϕ
Resistance	**W**	„	x	Pitch	$M\theta$	„	y	„	θ
Side	**S**	„	y	Yaw	$M\psi$	„	z	„	ψ

Fig. 5. Above: This diagram shows the axial convention adopted

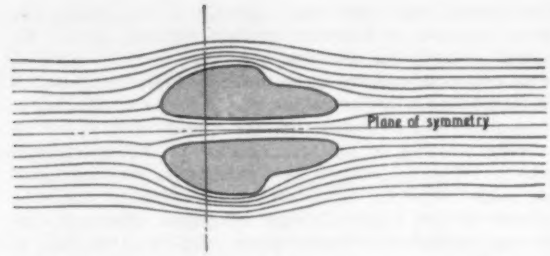


Fig. 6. Above: The free stream flow pattern around a pair of identical bodies, which are mounted one above the other, mirror-image fashion

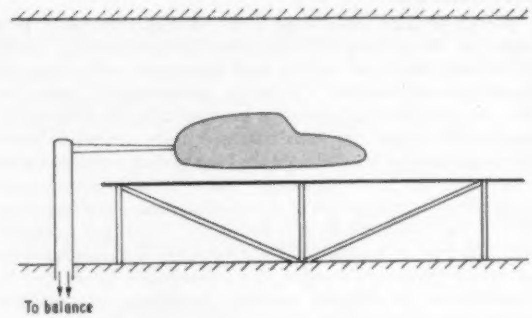


Fig. 7. Right: The model and the fixed road mounted in the wind tunnel

According to inviscid theory, the flow pattern is mirrored by a fixed boundary; or conversely, two identical models mounted wheels to wheels each have a flow pattern the same as that of a single car with a plain boundary passing beneath its wheels.

Illustrated in Fig. 6 is the double model, or mirror-image, test rig. It can be employed in one of two forms: two identical, complete models can be mounted on the balance, and the measured forces distributed between them or, more commonly, one completely detailed model is mounted on the balance while the less detailed mirror-image is rigged beneath it on the tunnel wall. An objection raised to this arrangement is that since air is viscous, friction at the boundary formed at the real road surface exerts some control over air movement at this plane. Comparison with other test arrangements indicates that this error exists, but that its effect is never great. Of more practical significance is the considerable difficulty of construction and accurate mounting of a second model inside the tunnel.

Installation of a short fixed road beneath the model, in the middle of the tunnel, Fig. 7, is a more simple expedient. There inevitably is a boundary layer over this fixed road surface, and this would not exist above the real road: the boundary layer is a stream of air that is slowed down by surface friction, and since the quantity flowing through any stream cannot change with distance, the thickness of the layer must increase as the velocity decreases. Unfortunately, the rate of growth may be greatly influenced by the presence of the car. The influence of the boundary layer of the road on the car might be reduced by accurate sloping downwards of the fixed road towards its trailing edge. Because of its simplicity, this rig has been widely used, and its probable errors carefully explored by both Heald[8], in 1933, and by Schmid[5]. Convenience of operation over a range of drift angles for two different tunnel installations justified the selection of this rig for the series of tests at the School of Engineering at Ardmore.

Tests in France, described by Romani[9], exemplified two variations on the fixed road theme:

1. A combination of the fixed road with the mirror-image rig, in which the road is very short, with its leading edge actually beneath the car. The image ensures that the correct flow approach pattern is obtained. Several positions of the road leading edge relative to the car in this set-up have been described by Lay[10], and some justification is offered for each of them, although in fact the different variants were primarily noteworthy for the similarity of the results that they yielded. Fig. 8 shows this rig, and indicates some of the different positions adopted for the leading edge of the road.
2. A fixed road, of normal relative proportions, provided with boundary layer control to eliminate the slope effect. Fig. 9 shows some of the approaches that have been made to this objective. Romani actually used the porous surface suction system, which removes a part of the boundary layer at a controlled rate. The forced vortex boundary re-energizing system, which has been described by Koenig-Fachsenfeldt, would appear to be less liable to operating errors. Still more desirable, from the operating point of view, would be the employment of fixed vortex generators to destroy the boundary layer by mixing it into the main stream; this line does not appear to have been explored.

An accepted standard of road simulation is by means of an endless, flexible belt, passing beneath the car at the correct relative speed, as shown in Fig. 10. This running road rig apparently has been known for many years, but it was the continuous research programme at Stuttgart that established its popularity. It certainly brings with it engineering complexity, particularly if the whole rig must be yawed across the tunnel to give the effect of drift angle.

When used with care, these different arrangements for simulation of the road beneath the model car have all produced satisfactory results. That this should be so can easily be understood from a study of Fig. 21, which will be seen in Part II of this article, to be published in the July, 1958, issue of *Automobile Engineer*; this illustration will show that with normal ground clearance, the road surface effect makes only a small contribution to the total forces acting on the car. According to Heald, a single model tested with

two different rigs gave values, for its resistance coefficient, differing only by 2 per cent. Schmid has tabulated tests of identical models, using four different tunnel rigs; the discrepancies between the results obtained with the different rigs vary between models, the greatest values being 3-4 per cent; the test with the running road rig gave the lowest value. It is thought that, for the making of speed predictions, any necessary test rig corrections would be best made before applying the complete series of allowances for wind tunnel wall effects, and mounting interference.

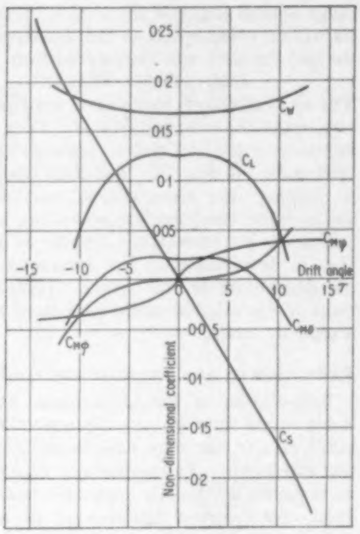
Tests at Ardmore

First, a preliminary series of tests was made, with the object of assessing present day practice in the field of automobile aerodynamics. The available wind tunnel is of the straight-through type, with a working section 30 in × 24 in, where the maximum possible air velocity is 200 ft/sec. A racing car was chosen as the vehicle for these tests, as it was considered to hold promise of aerodynamic development less restricted by other design considerations.

The model was made to one-eighth scale, which was the largest that could be accommodated in the tunnel; with the additional blockage of the supports and the fixed road, this proved a trifle large, so a one-tenth scale model might have been more satisfactory. Although the engine cooling system was represented in the model, it seems probable that the real car contained additional internal flow passages, which were not represented in the model. This model, which was designated car 1, is shown in its original state in Fig. 11.

First the tests were made with the model on its side, and the fixed road vertical, so that the three-component, aeronautical type balance, designed to measure lift and pitch, would actually record resistance, side force and yawing moment. The model and the road were then rotated through 90 deg, about the longitudinal axis, so that the balance then measured lift and pitching moment, but again covered a

Fig. 12. The six component coefficients of car No. 1. They are based on the wheelbase area and car axes, shown in Figs. 5 and 13, and are referred to the midpoint of the wheelbase at a height of 0·198l above the road



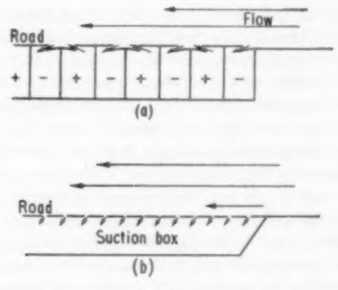


Fig. 9. Methods of boundary layer control over a fixed road

a forced vortex energization of boundary layer; b porous skin, to allow removal of small quantity of air from boundary layer; c vortex generators, to destroy boundary layer by mixing it with the main air stream flowing above

Fig. 8. Below: Combination of fixed road and mirror-image arrangement, showing the different relative lengths of road used by different investigators in this field

a Romani; b Heald and Lay; c Koenig-Fachsenfeld

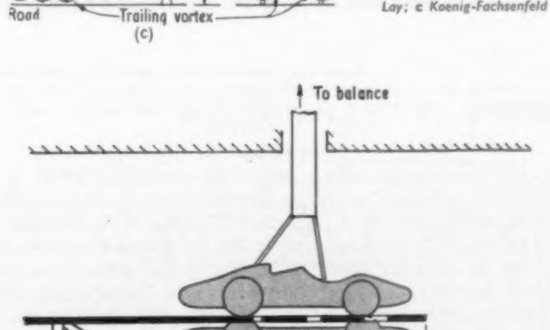


Fig. 10. With the arrangement illustrated below, an endless flexible belt is operated at the appropriate speed beneath the vehicle, to represent the relative motion between the road and the vehicle above

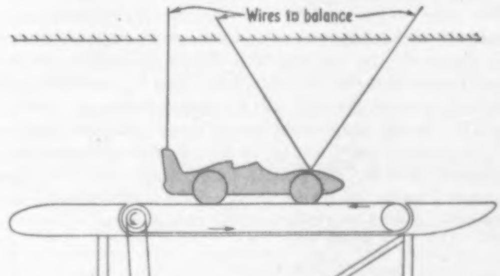
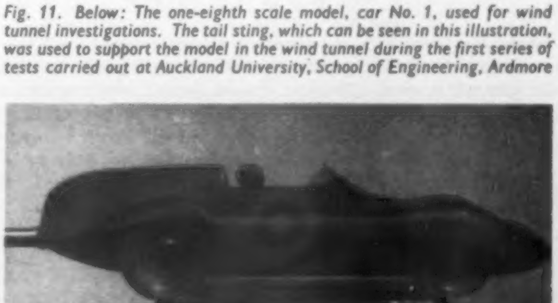


Fig. 11. Below: The one-eighth scale model, car No. 1, used for wind tunnel investigations. The tail sting, which can be seen in this illustration, was used to support the model in the wind tunnel during the first series of tests carried out at Auckland University, School of Engineering, Ardmore



range of drift angles of the model. This provided five of the six vector components of the aerodynamic force acting on the car; the sixth was then solved from the relationship:

$$DM\phi + LM\psi + SM\theta = 0$$

The six components so obtained were aeronautical coefficients referred to the wind tunnel axis. They have been transposed into automotive axes and are presented against a base of wind drift angle τ in Fig. 12. The sixth component was employed in making this transposition, and thus smoothed curve values were used for the operation, and the experimental points are not reproduced. Some of the models proved, in fact, to be asymmetric, but symmetry has been restored in the draughting of the curves. Tests made with modifications of this original model have been considered as forming a separate series.

Reduction to non-dimensional coefficients

Presentation of the aerodynamic test results in a non-dimensional form is very convenient for comparisons with other results that may have been obtained under different test conditions. Furthermore, it is useful in that the values so obtained are directly applicable to the full-scale machine. First, the observed figures must be corrected to take into account the supports and wind tunnel interference. It is a generally known procedure, and is, for instance, well described by Pope[11]. When this correction has been made, the values obtained are those for the model operating in the natural working surroundings. In the work done at Ardmore, the observed values were corrected for wind forces acting directly on the supports, and also for the effects of interference between the model and the supports. However, as only comparative results were required, correction was not made for the alteration to flow pattern, produced by the tunnel boundaries. Since the blockage due to the combination of model and road was quite large, it is possible that in this particular case the tunnel constraint corrections would have been appreciable, though they should never be large.

For these tests, and in fact for the preparation of the remainder of the data presented in this work, the conventional area chosen for the conversion of the results into non-dimensional coefficients was the wheelbase area S_w, and the related length l, chosen for the same purpose, was as shown in Fig. 13. In the most strict sense, the results are applicable only to geometrically similar bodies, so the body dimensions employed have no theoretical significance and their choice becomes a matter of convenience. The actual values for the conventional area and length of the model were:

$$S_w = 0{\cdot}495\ ft^2$$
$$l = 11{\cdot}375\ in.$$

A force coefficient C is:

$$C = \frac{F}{\frac{1}{2}\rho\, u^2 S_w}$$

and a moment coefficient C_M is:

$$C_M = \frac{M}{\frac{1}{2}\rho u^2 S_w l}$$

where the force F is measured in pounds weight, and the moment M, in this particular case, is in pounds-inches. In general, it would be more convenient to measure M in pounds-feet and l in feet. The density of the air in slugs per cubic foot is ρ, while u is the resultant wind velocity in feet per second. The expression $p = \frac{1}{2}\rho u^2$ represents the dynamic head in pounds per square foot.

For the purpose of the investigations, mutually perpendicular components of force were measured, together with their resultant moments about a reference point. The point chosen was at the centre of the wheelbase area, but at a height of $0{\cdot}198l$ above the road. Finally, the non-dimensional coefficients were transposed from wind tunnel to automotive axes, retaining this same origin. The main effect of the transposition is that at large drift angles the car resistance coefficient C_w becomes smaller than the aeronautic drag coefficient C_d. This is because the normal component of the wind force contains a forward vector, in relationship to the automotive axes, which may finally become greater than the drag, so that there is a nett forward force: this is, for example, the condition obtained with the sails of a yacht when it is sailing to windward. The equivalent negative value of C_w at large drift angles was observed by Heald.

Pressure distribution

Car 1 was drilled and fitted with a number of representative pressure tappings. These were constructed by drilling normal to the surface, at each required point, through to one of the internal passages. A $1\frac{1}{2}$ mm outside diameter plastics tube was threaded through the hole, cemented in position and, when the cement had set, trimmed flush. The inner end of the tube was threaded through the tail sting and down the balance struts to a multi-tube manometer, where about 20 readings were taken simultaneously.

A pressure plot round the central vertical longitudinal plane of the model is shown in Fig. 14. The form is typical, with a stagnation point on the nose, where the full dynamic head is recorded as the surface pressure. From this point, the pressure drops rapidly to a point towards the middle, or maximum thickness, part of the body, where the suction is at a maximum. Then the pressure rises again as the body becomes slimmer, towards the tail, where a small positive pressure is finally recorded.

There are considerable local pressure changes, particularly taking the form of high pressure areas in front of bulges on the outline, as for instance in front of the windscreen. The cockpit is in the region of lowest pressure and its internal pressure is probably further lowered by the deflecting action of the windscreen. As a result, the tendency inevitably is for all internal airflow to move towards the cockpit and to escape from it; this explains the universal complaints of fumes and, of course, the appearance of flames in the cockpit whenever a moving car catches fire. It would seem that drivers will ultimately accept closed cockpits for the sake of benefits obtained in respect of ventilation, even if not for any possible gain in performance. Apart from some increase in suction along the top of the tail fin, the centre-line pressures showed little general change with the angle of drift.

The surface pressure distribution around two cross sections is shown in Fig. 15, and the location of the sections is indicated in Fig. 14. These are actually half-plots, showing zero drift on one side and the 10 deg drift angle condition on the other. Here again, the effect of drift angle is small, except round the foot of the windscreen bulge in the $x=9$

Fig. 13. So far as dimensions are concerned, the convention chosen for converting the experimental results obtained at Ardmore into the non-dimensional coefficients is as shown in the plan and elevation below

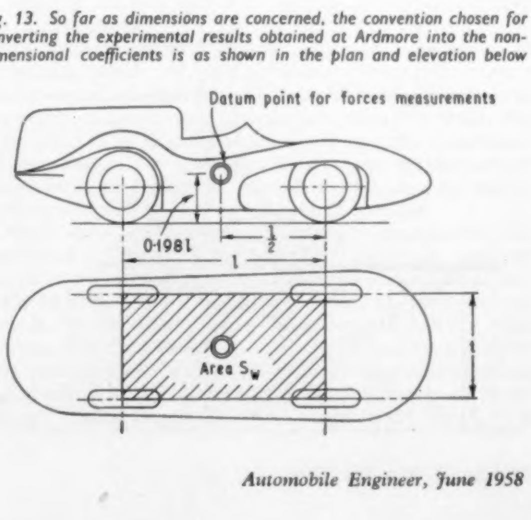
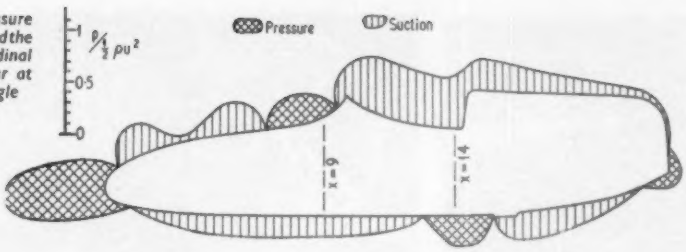


Fig. 14. Pressure distribution around the central longitudinal section of the car at zero drift angle



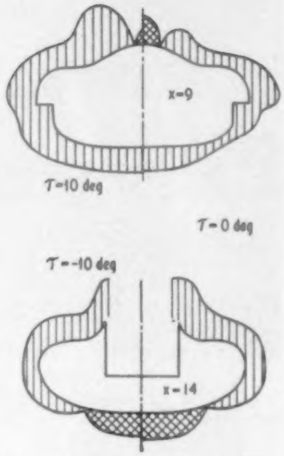


Fig. 15. Right: Two diagrams showing the pressure distribution around the cross sections x = 9 and x = 14, as shown on the longitudinal section above

section. However, Sawatzki[12] has shown that the drift angle is liable to have a considerable effect on the pressure distribution towards the ends of the vehicle, particularly the rear.

For this particular model, the pressures at both the front and rear wheel arches were in the order of —0·5p, agreeing well with the values for the two middle sections, and like them, varying little with the drift angle. From these figures, it would seem generally wiser to provide for the discharge of cooling air from the sides of the car: if it is discharged at the top, the cooling air is liable to flow over the driver's face and cause discomfort. In any case, the local pressure at the top is subject to considerable variation, and at the bottom, there just is not sufficient space for the hot air to escape freely. There is always high pressure zone at the base of the windscreen, and this is commonly used to force air through ventilation intakes. Of course, there should not be a hot air outlet in front of the ventilation intake.

Conclusions from the first series of tests

These tests on the model of the complete car have been analysed entirely as a separate series. Initially, the general aerodynamic characteristics of the car had been determined. It was considered that the resistance was unduly high for an enclosed-wheel body, and there was an absence of aerodynamic stability, which was rather unexpected in view of the finned shape. Certain shortcomings of the equipment used for this initial test had also become apparent, the most serious being the large aerodynamic moments of the model support cradle, which overwhelmed the small yawing moment of the model.

The streamline pattern around the car was explored with a wool-tuft, and was found to have considerable lateral components. Even near the longitudinal centre-line above the nose there was a big outwards horizontal component, while beneath the tail there was a correspondingly large inward flow from the sides. Although the body of this particular car is of relatively flat section, this lateral displacement of the streamlines becomes understandable if the complete, free stream body, consisting of the combination of the car with a mirror-image is envisaged: ignoring the gaps, it can be seen that this composite body is of tall, narrow form.

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ELECTRICALLY-DRIVEN EXHAUSTER

A NEW exhauster, the E.240 model, has recently been introduced by Feeny and Johnson Ltd., of 134-136, Ealing Road, Wembley, Middlesex. It is designed for the increasing numbers of small vans, pick-up vehicles, and private cars that are being equipped with compression ignition engines, and which are used for towing caravans and trailers fitted with vacuum brakes. Since compression ignition engines cannot provide manifold vacuum and there is seldom room for fitting a conventional exhauster in the installation, some other source of vacuum supply is required. Incidentally, even if it is possible to fit a conventional exhauster, it is difficult to drive it at a suitable speed, in view of the wide range of speeds of these small engines.

The new exhauster is driven by a 12 volt motor. It can be fitted in almost any suitable place on the vehicle, for instance, in the boot of a private car. The arrangement of the unit is such that the motor only operates when the degree of vacuum in the reservoir falls below a predetermined level. When the tractor, or towing vehicle, is operated without the trailer, the exhauster is isolated by means of a combined standard coupling and isolating switch assembly No. AD.290.

The action of connecting the pipeline of the trailer brake to the towing vehicle, in the normal manner, has the effect of making an electrical connection, which completes the circuit to the motor. When the depression falls below a predetermined level, the motor starts automatically. The switch units are normally set to cut in at approximately 20 in of vacuum and to cut out again at 24 in of vacuum.

Ford dash facia treatment: that on the left is on the Continental III, while the right-hand one is on the Thunderbird. In one, the instruments are deeply shrouded and in the other they are placed well forward, to obviate reflections at night, particularly on the ends of the wrap-round windscreen

American Bodywork

Styling Problems Set by the Adoption of the Twin Side-by-Side Headlamp Arrangement

APART from the trend towards the adoption of twin side-by-side headlamps, there are few general characteristics that can be said to be typical of the latest American trends. One of these few is the tendency towards employment of upswept fins at the rear. This, together with the swept round windscreen and rear light arrangement, is not conducive to harmonious styling. In fact, the American cars this year can be said once again to be noteworthy for their angularity of appearance and the excessive use of chromium plated adornment. Safety features, such as good all-round visibility, special door locks, and padded facias are much in evidence.

Most of the manufacturers effect changes annually to obtain variety by modifying some of the panels and retaining others of their earlier models. There is even evidence to suggest that some are designing their bodies initially so that subsequently such modifications can be readily effected. Apart from these features, each American group of manufacturers appears to be working fairly independently, rather than following others, so far as style is concerned. For example, some have adopted upswept, fin type rear wing crowns; others favour horizontal lines; and yet a third group employ the outwardly-flared fin type of design.

Front end design, particularly, is in a state of flux. The reason for this is the difficulty of incorporating the twin side-by-side headlamp arrangement in a conventionally styled front end. A wide variety of different methods has been employed and finality has certainly not yet been reached. Many of the arrangements currently adopted are far from satisfactory; however, when the stylists have had more time to experiment, no doubt the problems will be solved, as have most of those concerning wrap-round windscreens and rear lights.

So far as appearance is concerned, the main problem when twin side-by-side lamps are employed is treatment to reduce the excessive width of the wing crown which, up to the present, has seemed to be inescapable. Most manufacturers have used a pressed line, or channel, or a chromium plated strip along the crown. This accentuates the length, but hardly seems to give satisfactory results, so far as reduction, either real or illusory, of the width is concerned.

Nash differ from all the others, in that the pressed line on their models is offset towards the outer edge, instead of

Extremely large diameter stop and tail lamps are employed on the Ford Thunderbird, and the styling of this end has been designed to harmonize with that of the front end

being centrally disposed along the wing crown. The arrangement on the Ford Continental III is an interesting alternative. On this model, the lamps are not side-by-side, but are mounted in pairs, one above the other, with the lower lamp in each pair offset towards the centre of the vehicle. In fact, this might be described as a V-arrangement. It has the advantage that it could be harmonized readily with the outwardly-flared fin type rear end arrangement that has been popular recently.

A noteworthy feature of the arrangement of the Plymouth Fury is the simplicity of the front end panelling assembly, which is discussed later in this article. The method of accommodating the twin headlamps on the Champion Sedan hardtop, which is simply to spot-weld pressings on each side of the lamp housing, is obviously only a temporary measure, intended to meet the requirements dictated by sudden changes of fashion. There would appear to be much to be said for combining the front end treatment of the Ford Thunderbird with the rear end of the Chevrolet Impala with, of course, slight modifications to both to blend the two harmoniously together.

It is of interest to note that the Continental III has the rearwardly raked rear light arrangement introduced in 1955 by Pinin Farina on a body built on the Fiat 500 chassis. The advantages of this arrangement are manifold. For example, the roof panel and head lining arrangements are simpler than they could otherwise be, and a flat glass can be used, with a consequent saving in cost. In this case, the centre portion of the glass can be raised or lowered to give through-ventilation in very hot weather. Since the glass is protected by the overhung roof, it can be of lighter gauge than that employed in more conventional layouts. Moreover, there is much less tendency for the glass to become obscured by drops of rain falling on it. The rear quarters are of such a shape that they offer a minimum of obstruction, so far as the range of vision is concerned. At night, the glare from headlamps of following cars is reduced because of the slope of the glass. During the daytime, the overhung canopy protects the interior trim from the effects of direct sunlight. It also provides welcome shade for passengers at the rear.

With regard to interior arrangements, the adoption of power actuation for seat and window movement has facilitated control layout. In particular, it is now possible to keep the door trim panel completely clear of controls. Apart from this, the nett gain, so far as simplicity is concerned, has been offset by the insatiable American demand for gadgets and by the increased complexity of other controls, such as those for heating and air conditioning. It seems likely that automatic controls will be increasingly adopted for many of these services.

Most of the American manufacturers fit some form of padding between the head lining and roof panel. Employment of materials that have thermal insulation properties

Above: A heater duct forms the arm-rest on the door of the Ford Continental III; its forward end connects with a duct on the scuttle side

Below: On the Edsel Ranger, a large grille for the radio speaker is incorporated in the top of the dash facia and the radio is below it

A neat twin, side-by-side headlamp arrangement has been adopted on the Ford Thunderbird, and the wide wing crown feature is repeated at the rear end of the vehicle

There are eighteen variants of the Edsel. This illustration shows the Ranger four-door hardtop version

would appear to be particularly desirable in cars that are to be fitted with refrigeration equipment. This is because it reduces the load on such equipment, and the cost of insulation is less than that which would be involved in providing for refrigeration of the greater capacity that would be needed if the insulation were not employed.

Ford

The much publicized Ford Edsel Ranger has many features in common with the other American designs, although the front end is unusual in that the traditional vertical radiator grille is employed. This grille is a little inconsistent with the horizontal features of the remainder of the front end design. The styling of twin side-by-side headlamps presents considerable difficulties. In this particular instance, a line is pressed prominently along the crown of each wing. Above the central portion of the radiator grille, the bonnet is pressed locally to form a shape reminiscent of the bonnets of the pre-war era. A line is pressed along the crown, and a circular motif is mounted near the front end of this line.

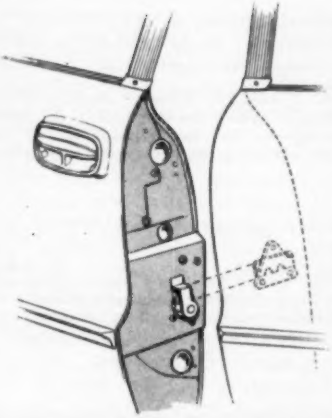
At the rear end, the styling is designed to harmonize with that of the front end; the general layout of both is shown clearly in the accompanying illustrations. The rear door hinge pillar, which is of substantial section, extends only up to the waist line. An interesting feature of this door arrangement is that it not only extends well to the rear, and occupies a position that would otherwise be filled by the rear quarter panel, but also it is extended up above the waist line to form a continuation of the rear quarter panel of the canopy. This extension above the waist comprises two panels, an inner and an outer one, and the trailing edge of the glass on the rear door is supported between the two, as it is raised and lowered by the winder type handle. As can be seen from the illustration of the rear end of the vehicle, the extension, which is chromium plated, is shaped like a wrap-round end of the rear window. Thus, so far as appearance is concerned, the effect of a wrap-round rear window is obtained without resort to unnecessary expense in the moulding of the glass. The range of visibility to the rear is not noticeably less than it would be if the sides of the glass panel were extended round in the normal manner.

On the rear door, the glass has a rubber sealing strip on its forward edge; as it is raised, it is moved forwards during the last few inches of the motion, to seal against the trailing edge of the window on the front door. Inside the vehicle, a plastics headlining is employed, and this is backed by a glass fibre padding. Presumably this padding is for both noise and heat insulation: it could hardly be very effective in preventing reverberation, since the plastics lining below it is almost bound to reflect noise.

As with most of these American cars, several variants are made, all basically similar. One of the variants of the Edsel is the Citation. This has a roof and rear light arrangement that is different from that of the Ranger, already described. A channel section pressed in the roof continues the lines of the channel on the boot lid, and the rear light is wrapped further round the rear quarters. The rear quarter panel on each side of the canopy is not extended on to the door, but is formed by the upper end of the door shut pillar.

From a superficial examination, it would appear that a number of the panels and components are common to many of the Ford vehicles. For instance, the Edsel Citation roof, rear light and front windscreen, as well as the front door, appear to be common with those of the Mercury Monterey. Both the front and rear end styling of these two

Rear end of the Edsel Ranger four-door hardtop. A chromium plated extension of the panelling over the rear door handle continues the lines of the wrap-round ends of the rear light



Above is a line drawing of the shrouded, rotating safety-lock arrangement on the door of the Chrysler Imperial le Baron, which is shown in the right-hand illustration

models are, however, entirely different. On the Monterey, outwardly-flared rear wings are employed, but the flared portions are shaped to resemble a rocket missile, the tail end of which is formed by the elaborately designed rear lamp, a reflector being mounted on the extreme rear end of its bullet-shaped glass.

The Ford Thunderbird is another example of styling to suit twin side-by-side headlamp arrangements. In this instance, the relatively large flat area over the headlamps is broken up by a channel section pressed along the crown line. A ring motif is mounted at the forward end of this channel. As can be seen from the illustration, the outwardly-flared hood over the lamps is formed in the wing pressing. The sides of the bonnet lid are swept up and extend out to about an inch of the channel section on the crown of each wing. A wide air intake duct is incorporated in the centre of the bonnet, and air intake louvres for the heating system, which are pierced in the scuttle, extend the full width of the base of the screen.

To conform with the front end arrangement, the fin type rear wings are flared outwards. Also, twin side-by-side tail lamps, of exceptionally large diameter, are incorporated beneath hoods formed by a rearward extension of the bonnet lid. As can be seen from the illustration, a channel section is pressed along the centre of the boot lid and is continued forward over the rear decking and the parcels shelf inside the vehicle. The rear window is only slightly curved and is shrouded by a hood formed by a rearward extension of the canopy top and both of the rear quarters.

This vehicle is one of the better examples of American styling, since it is not over-decorated with chromium plating. The sides are broken up by pressed shapes. One is a line extending from the hood over the front lamps and coming back to about three-quarters of the way along the doors. There it is swept down, to join a torpedo-shape pressed in the rear door and quarter panels. The nose of

Three-piece, raked rear light arrangement on the Ford Continental III

The front end arrangement of the Ford Continental III, showing the V-layout of the headlamps, which would probably harmonize well with outwardly-flared rear wings

Left: A noteworthy feature of the front of the Plymouth Fury is the simplicity of the panel arrangement and the neat installation of the twin side-by-side headlamps above the grille

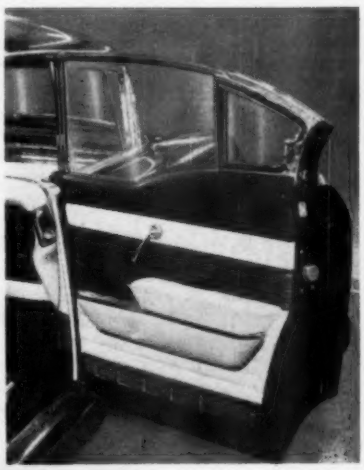
Below: At the rear of the Plymouth Fury, the trailing ends of the wing panels are closed by chromium plated filler pieces, on which the moderate-size tail lamps are mounted

this torpedo-shape is about one-quarter of the distance from the leading edge of the door, and its barrel extends to the extreme rear end of the vehicle, where its lines are continued by the wrap-round portions of the two-piece rear bumper. The line of the top of the outwardly flared, fin type rear wing on each side is extended forwards through the press-button type door handle, and continued some 8 or 9 in further on by a pressed line on the door.

Inside the vehicle, the instrument panel on one side and the large glove box on the other are deeply recessed, the facia forming a hood over both. On the driver's side, of course, this hood prevents reflections from the instruments on to the windscreen at night, while the hood on the other side is incorporated simply to give balance to the arrangement. The radio is mounted between these two hoods. A large tunnel is incorporated between the two front seats, to accommodate the automatic transmission. The heater controls are installed on its forward end, while switches to control seat adjustment are mounted at its rear end. Between the two is an ashtray with a lift-up lid.

The Continental III, again, is not over-adorned with chromium plate, except at the rear end. It represents yet another way of accommodating twin headlamps. As has already been stated, a V-arrangement is employed, and this would appear to blend well with the outwardly-flared rear wing fin arrangement that has become popular recently. However, almost vertical rear fins are used on this model.

Right: The only control on the trim panel of the rear door of the Cadillac Sedan de Ville is the lever that actuates a rotary lock



Left: Pull-out type door handles are employed on the Chrysler Imperial le Baron. These have the advantage that they are almost flush with the surrounding panel

The design of the rear end is unusual in that a full-width dummy radiator grille is employed. On each side of this grille, there are three lamps arranged in line. These lamps, of course, are the tail and stop lamps, the direction indicators, and the reversing lamps. The lower edge of the grille is formed by the bumper, while its upper edge is finished by a large chromium plated capping. It is surprising that an elliptical form has been chosen for this framing, since a rectangular shape would have harmonized well with both the rear light and front grille arrangement.

As has already been mentioned, an interesting feature of this vehicle is the rear light, which is raked backwards. The glass is flat and is in three pieces. Vertical pillars separate the side pieces from the wide centre piece, which can be raised or lowered. The actuating mechanism

for the centre glass is power-operated, and controlled by a switch inside the vehicle. On such a large vehicle, the styling of this arrangement appears to present few difficulties now that, following the advent of wrap-round rear windows, the general public have become accustomed to rearwardly raked lines on the quarters of the canopy.

Another unusual feature is the dash facia arrangement. All the instruments are mounted on a separate panel, which is secured well forward of the main portion of the facia, immediately above the steering column. This is a particularly useful feature, so far as servicing is concerned, although it places the instruments closer to the eyes than is necessary, and the range of focusing required when looking from the instruments to the road and vice versa is fairly large. In this car, considerable attention appears to have been devoted to the grouping of controls in such a way that they are easy to operate. The headlining, like that on the Thunderbird, is perforated hide backed by a noise-absorbent glass fibre, and the roof panel is slightly dished to accommodate this material.

Chrysler

The Chrysler Imperial le Baron is a good example of the latest trends in door trim styling. As can be seen from the accompanying illustration, the panelling above the armrest is dished to provide ample elbow room. The base of the armrest forms a pocket, access to which is gained by lifting a padded lid. This lid is secured in the closed position by a press-stud on a flap, midway between its ends. Forward of the armrest, there is an unusual form of door lock release handle. As can be seen from the illustration, it resembles a clutch or brake pedal, but is hand-operated. It is difficult to see what aesthetic merits this arrangement has, but from the practical point of view it probably represents a simple method of remote control of the lock. Above it, mounted on the waist rail, is a row of switches for controlling the electrically-actuated window lift mechanisms.

Another unusual feature of the door lock arrangement is that the exterior handles are of the straight pull-out type, as distinct from the hinged pull-out type. As can be seen from the illustration, this arrangement has the advantage that the handle lies almost flush with the panelling, and it is probably easier to operate than some of the other types. A rotating sprocket type lock is fitted to the rear edge of each door. A shroud plate is fitted over the sprocket in such a way that when the striker plate engages the sprocket, the shroud embraces both components. This arrangement has been adopted so that, in the event of a crash, the striker plate cannot jump out of engagement with the sprocket, and thus allow the door to fly open.

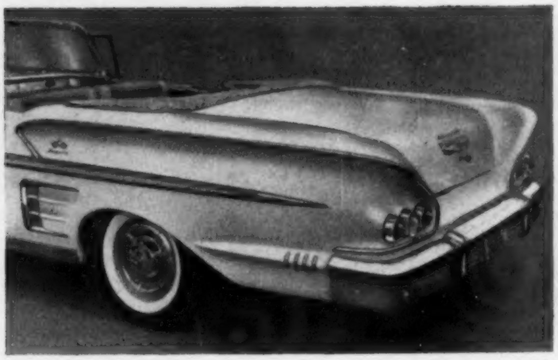
Simplicity of the front end panelling is a noteworthy feature of the Plymouth Fury. The grille extends the full width of the body and the twin side-by-side headlamps are mounted on it, immediately below the overhanging leading edges of the wing pressings. Between the headlamps, the bonnet lid shuts down on to the horizontal top bar of the grille opening. Below, the bumper is of a fairly elaborate shape, which is more or less a mirror reflection of the shape of the hoods over the headlamps and the horizontal bar between each pair of them.

The centre portion of the grille extends down below the raised portion of the bumper. The advantages of this arrangement are that there is no skirt panel, and the wing pressings are extremely simple. It also represents a simple

Left: Unusual winged side lamps are mounted on the panelling immediately above the single headlamps on the Studebaker Silver Hawk model

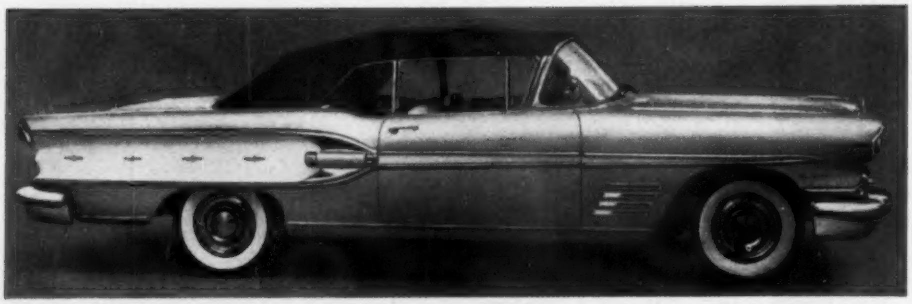
An unusually neat instrument and control panel installation is employed on the Studebaker Champion, and the rubber floor covering is embossed and speckled so that it closely resembles woven textile carpet

On the Studebaker Champion Sedan, the rear wing fins are separate panels welded in position on the pressings of the earlier version of this model



Of these two completely different rear end treatments, that on the left is the Chevrolet Impala, while the other is the Pontiac Strato Special. Both are simple by comparison with most other examples of American styling and harmonize well with the side-by-side headlamp layouts at the front ends

Elaborately heavy side and rear end treatments, exemplified by this Oldsmobile Super, are common among the large American cars



Rocket themes, such as this on the Pontiac Bonneville, are widely used by the Americans

The two views below show the front and rear ends of the Buick Special; they exhibit an unusual contrast between rounded and angular features

way to accommodate the twin side-by-side headlamps, although in the arrangement adopted, the problem of reducing the width of the top of the wing pressing does not appear to have been satisfactorily solved. Possibly this might have been done by extending the sides of the bonnet lid up over part of the wing crown. However, this measure would, of course, add to the weight of the lid and might introduce problems with regard to the spring balancing of the hinge mechanism. There is, of course, much to be said for the full width grille arrangement, in that the provision of an adequate flow of air for brake cooling presents no difficulties. A problem might arise, however, with regard to water and mud thrown forwards off the wheels and going through the grille on to the bumper and apron.

At the rear of this vehicle, the fin type wings are upswept. These pressings, again, are of simple construction. The opening at the rear end of each wing panel is closed by a chromium plated filler piece, with a bezel round its edges. On this filler plate is mounted the rear lamp. As at the front, the ends of the bumper extend round the sides to protect the panelling.

Studebaker

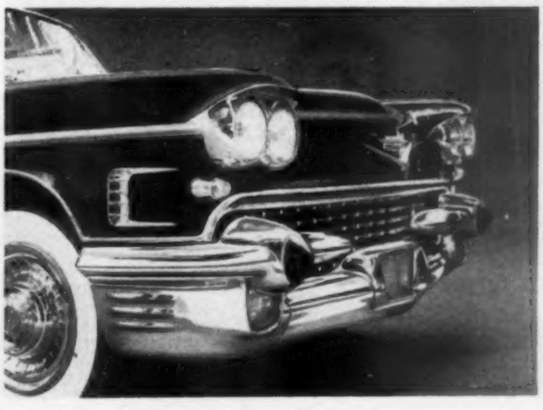
Economy of retooling for new models has been achieved in a number of ways by Studebaker. For example, on the Silver Hawk coupé, the outwardly-flared fin of each rear wing is formed by a separate panel superimposed on the old design. The joint between this panel and the wing is concealed at the lower edge by a chromium plated strip and at the upper edge, which sweeps up over the rear quarter and down on each side of the boot lid, by a strip of plastics material, stuck on and painted the same colour as the rest of the panelling. A variety of boot and bonnet lids are fitted to the different models; this helps to modify their appearance considerably.

At the rear end of all the models, there is no skirt panel at the lower edge of the boot; instead, the joint at the rear of the boot floor is concealed by the apron, which is spot-welded to it and extends out into the bumper section. The housings for the rear lamps are separate pressings. These overhang the apron and form the rear ends of the wings. They are spot-welded in position, right-angle flanged butt joints being employed.

The hinged ventilating panels at the forward edge of the front door have glazing rails on all but their trailing edges. They are hinged about $1\frac{1}{2}$ in from their forward edges, so when the panels are opened, the glazing rail along the leading edge does not encroach upon the range of vision of the driver. Despite the small distance between the hinge line and the leading edges, the panels can still be turned through more than 90 deg to deflect air into the vehicle instead of extracting it. This ventilating panel assembly is framed in a rubber moulding instead of the more usual chromium plated frame. The door has a winder-actuated, drop-glass, but the rear quarter light is simply a glass panel with a glazing rail fitted round its edges. It is hinged at the forward edge, and secured by a toggle clip at the rear edge. A wrap-round rear light arrangement has been adopted.

The Studebaker Champion Sedan hardtop, unlike the Silver Hawk, just described, has a twin side-by-side headlamp arrangement. To accommodate the headlamps, three extra pressings are welded on the old single-headlamp housing. One is fitted on each side, and the third on the front to form the hooded bezel in which the lamps are carried. In many other respects the design is similar to that of the Silver Hawk, but the joints round the fins on the rear wings are concealed by chromium plated finisher strips. The rear lamp arrangement also is different, in that reversing lamps are incorporated in the trailing edges of the fins, while the stop and rear lamps are mounted below in the pressing that finishes the rear end of the wings. Inside this vehicle, the floor covering is a dark grey rubber mat laid on underfelt. The rubber mat has a white speckle pattern and is embossed to resemble woven carpet; in fact, at a casual glance, many people would take it for carpet.

Right: On the Chevrolet Biscayne, the lamps are styled to resemble the ends of rockets



Below: Aeronautical influence is a prominent feature of the basic theme of the styling of the front end of the Cadillac 62, particularly with regard to the ends of the bumper

General Motors

There are a number of interesting detail features on the General Motors models. Among these is the headlining on the Oldsmobile 88 Holiday sedan. The unusual feature of the arrangement is that a cloth headlining is not employed; instead, a sheet of sponge rubber, or possibly sponge plastics, is stuck on to the roof panel and firmly supported by five chromium plated listing strips. The material has a white finish and its surface is such that at first sight it appears to be cloth. Possibly some saving in material cost is effected by the employment of this type of head lining. However, the principal economy is probably obtained by virtue of the fact that the labour costs involved in fitting

Left: The estate car version of the Nash Rambler has only a few minor modifications this year. Among these is the incorporation of fin type rear wings, which certainly do not serve any useful function aerodynamically

Right: A small pressing and a chromium plated finisher close the end of the rear wing on the Studebaker Silver Hawk model

one sheet of sponge material to the roof are appreciably lower than if a cloth headlining, together with a sheet of insulating material, were fitted separately.

As has already been stated, many of the American cars currently in production have a sheet of insulating material between the headlining and the roof. Different materials are used for this purpose: in some models, glass fibre is employed, while in others, sponge rubber or sponge plastics is used. The headlining is of either cloth, hide or sheet plastics. If either of the two latter materials is used, it is generally perforated, to enable the material to perform its function of noise absorption, as well as insulation. Noise insulation and noise absorption are, of course, two entirely different functions: absorption materials are used to prevent or reduce reverberation. It is of interest to note that the Cadillac 62, as exhibited at Geneva, was equipped with a perforated hide headlining without the heat insulation and noise absorption backing.

The arrangement of the doors of the Cadillac Sedan de Ville is a noteworthy example of good design. As can be seen from the accompanying illustration, the only control lever on the door is that for actuating the lock. The window lift is controlled by a switch on a forward extension of the armrest. A small glass ventilating panel is installed immediately behind the drop-glass of the rear door. This not only enables draught-free ventilation to be obtained, but also the vertical frame member on which its forward edge seats also serves as a guide channel for the drop-glass. As on most of the American cars, the air from the heater is carried by ducts through the doors and their pillars. In the illustration of this particlar vehicle, the duct in the centre pillar can be seen, as well as the outlet louvres in the base of the rear door. Since the pillar extends only up to the waist rail, it is essentially of sturdy construction and tapers, cantilever fashion, from a relatively small section at its upper end to a large section at its base. As on many of the American cars, a powerful two-link and over-centre coil spring arrangement on the lower hinge holds the door in the open position to facilitate entry.

Many American manufacturers are at present preoccupied with the problems of designing rear end styles to harmonize with the twin side-by-side headlamp arrangements at the front. Among the General Motors models that exemplifies this trend is the Pontiac Strato Chief. On this vehicle, twin side-by-side headlamps are employed, and each pair is mounted in a hooded housing, similar in form to that employed at the front of most American vehicles. This arrangement brings with it the disadvantage of the rather unsightly wide wing-crown that causes so much difficulty with front end styling. A more pleasing appearance is obtained on the Chevrolet Impala, shown in an accompanying illustration. Although three lamps are fitted horizontally in line on each side, a twin-lamp arrangement could be equally well accommodated with this layout.

Rockets seem to be a basic theme in the styling of a number of American cars. The rear end of the Oldsmobile Super is an example of this, as also is the front end of the Chevrolet Biscayne, in which the twin side-by-side headlamps with the twin side-by-side indicator and parking lamps below them are styled in such a way as to resemble the front ends of rocket or guided missile installations.

To accommodate the new twin side-by-side headlamps on the Champion, three pressings are welded to each original, single-headlamp housing

Recent Foreign Publications

Brief Reviews of Current Technical Books

Untersuchungen über die Zweckmässige Führung des Auspuffrohres bie Diesel-Kraftfahrzeugen. (Investigations Regarding the Suitable Positioning of the Exhaust in Diesel-Engined Vehicles). Deutsche Kraftfahrtforschung No. 110

In German. By Otto Bode, Prof. Dr. Ing., and Martin Dreier, Dipl. Ing.
Düsseldorf: VDI-VERLAG G.m.b.H. 1957. 11¾ × 8¼. 14 pp. Price DM 9.50.

This monograph outlines the adverse effects of diesel engine exhaust gases and the requirements that should be imposed to ensure efficient exhaust dissipation. The results of tests carried out with different exhaust arrangements are discussed, and their value is enhanced by a considerable number of informative half-tone illustrations covering various aspects of the subject.

Untersuchung über den Einfluss der Stossdämpfer auf die Zwischen Rad und Fahrbahn Auftretenden Senkrechte Dynamischen Bodenkräfte (Investigations concerning the Influence of Shock Absorbers on the Dynamic Forces Occurring between Wheel and Road). Deutsche Kraftfahrtforschung No. 105

In German. By Erich Marquard, Prof. Dr. Ing.
Düsseldorf: VDI-VERLAG G.m.b.H. 1957. 11¾ × 8¼. 32 pp. Price DM 14.20.

The author of this monograph is well known for his theoretical and practical work in the field of vehicle dynamics. In the work, he considers the effect vehicles have on the road, and makes particular reference to design factors likely to reduce road damage. From thorough theoretical investigation, substantiated by rig tests, the author comes to the conclusion that vertical impacts upon the road can be reduced to an appreciable extent by a judicious selection of vibration dampers. It is considered that further road tests will be required to substantiate the author's conclusions but even so, this paper is thought-stimulating and encouraging, in so far as the application of rational analysis to vehicle design is concerned. It is a pity that a key to the lists of symbols has not been provided, since its absence makes reading a little difficult. This applies particularly to the more complicated equations, to decipher which, recourse had to be taken in some instances to the author's previous paper in *ATZ*. However, this criticism should in no way be thought to detract from an otherwise most interesting monograph.

Untersuchungen über die Ablagerung von Bleiverbindungen in Verbrennungsmotoren bie Verwendung Verbleiter Kraftstoffe (Investigations Regarding the Deposit of Lead Compounds in Internal Combustion Engines). Deutsche Kraftfahrtforschung No. 106

In German. By Robert Rost, Dipl. Ing.
Düsseldorf: VDI-VERLAG G.m.b.H. 1957. 11¾ × 8¼. 26 pp. Price DM 13.60.

This monograph deals with tests which, according to the author, have been made by employing a microscope, instead of relying on purely chemical analysis, for the first time to determine the composition of residual products deposited in the combustion space of internal combustion engines. The tests were also successful in the determination of the various lead-sulphur deposits found in the combustion chambers of vehicles. These deposits were analysed on the basis of their crystalline structure.

In the first part of the monograph, the author deals with his findings under the microscope, while the second part covers tests carried out with the addition of various combinations of lead oxides and sulphur introduced into the engine in a highly pulverized form. The purpose of all these tests was to ascertain whether any of the various combinations could be regarded as the primary, or the starting combination, and whether other combinations were formed from the primaries, under the influence of pressure and temperature.

At the end of the monograph there is an analysis of the working conditions which, at any particular time, would affect the individual combinations and the texture of the structure. It is considered that this work will be of particular use to engineers interested in the finer points of engine combustion processes, and it can be recommended as a model of thorough and painstaking research of this kind.

Untersuchungen über die Wirksamkeit von Kotflügeln. (Investigations on the Effectiveness of Mudguards). Deutsche Kraftfahrtforschung No. 109

In German. By Paul Koessler, Prof. Dr. Ing., Hans Rauner Engels, Dipl. Ing., and Manfred Mitschke, Dipl. Ing.
Düsseldorf: VDI-VERLAG G.m.b.H. 1957. 11¾ × 8¼. 13 pp. Price DM 9.50.

Considering the number of different types of mudguard evolved for motor cars, it is surprising that no rational research has been carried out to determine the best configuration. This monograph fills a long-felt want in this respect, and the authors are to be congratulated on what, on the surface, looks a rather simple type of research but which, as they show, is most interesting and worthwhile. After considering the theory of motion of a particle thrown off the moving wheel, the method of testing mudguard effectiveness is described in some detail, and the results of typical tests already carried out are given. The report concludes with a brief statement of requirements for efficient mudguard design.

Prüfung von Dauerbremsen an Kraftfahrzeuganhängern (The Testing of Continuously Applied Brakes for Trailers). Deutsche Kraftfahrtforschung No. 104

In German. By Guido Müller, Dr. Ing.
Düsseldorf: VDI-VERLAG G.m.b.H. 1957. 11¾ × 8¼. 17 pp. Price DM 11.20.

This report is a continuation of the earlier series, by other authors, dealing with various aspects of road vehicle brake design. In it, trailer brakes are considered, and the results of extensive tests, dealing mainly with continuous brake applications and the performance of various types of brake linings, are given in detail. The report concludes with a statement of the requirements that should be met with brakes of this type, and suggests a simple test procedure to ascertain whether these requirements are met.

Krafte in Einrichtungen zur Verbindung von Kraftfahrzeugen mit Einachsanhangern Uber 20 km/h Hochstgeschwindigkeit (Forces in the Couplings Between Motor Vehicles and Single-Axle Trailers Operated at Maximum Speeds of More Than 20 k.p.h.). Deutsche Kraftfahrtforschung No. 112.

In German. By Dr. Ing. O. Bode and Dipl. Ing. Heinrich Meyer.
Düsseldorf: VDI-VERLAG G.m.b.H. 1958. 11¾ × 8¼. 22 pp. Price DM 12.20.

This monograph is a report on an investigation instituted to obtain data for both the design and testing of components of couplings between vehicles. For these tests, two passenger cars and one truck, each towing the same single-axle trailer, were employed. Also a trolley bus, towing a different single-axle trailer, was used. From the experiments, the maximum values of the forces on the coupling elements were determined.

In the case of the car-trailer combination, the maximum forces

obtained during normal running were found to be largely independent of conditions such as road surface and speed. When the brakes were applied, the maximum values of the forces were, of course, considerably higher than during normal running, and were dependent on external factors and especially on whether the trailer was equipped with a brake actuated by the over-run forces.

With the motor truck and trailer, the values of the forces experienced during normal running depended to a great extent on the conditions under which the tests were made. When the brakes were applied, the maximum values of the forces were generally the same as, but in some instances were lower than, those obtained during normal running. These forces were also dependent on conditions under which the test was made, in particular on the centre of gravity of the trailer and its load. The maximum values of the forces, both under normal running and braking conditions, were, of course, greater than those obtained with the car-trailer combination.

Apparently, with the trolley bus and trailer, the maximum values of the forces obtained were largely independent of the conditions governing the test. They were, in fact, between the maximum values obtained for the trailer towed by the passenger car and the motor truck.

Untersuchungen an Deichselkraftgeregelten Bremsen von Kraftfahrzeuganhängern (Investigations Concerning Drawbar-Controlled Brakes for Lorry Trailers). Deutsche Kraftfahrtforschung No. 108.

In German. By Herbert Merz, Dr. Ing.
Düsseldorf: VDI-Verlag, G.m.b.H. 1957. 11¾×8¼. 73 pp. Price DM 34.

Applied research relating to road transport in Germany is sponsored by the Transport Ministries of the various *Länder*. This work, which is for the general benefit of vehicle manufacturers, as well as users, is carried out at various Technical High Schools and is subsequently made available by publication through suitable agencies. The specialized institutes affiliated to the Chairs of Vehicle Engineering at the Technical High Schools usually tend to specialize in certain fields of vehicle design. At Hanover, the Institute headed by Prof. O. Bode concentrates on brake problems. The work of this Institute has always been of a very high standard, not only so far as theoretical investigations are concerned, but also with regard to application to practical requirements. These reports, a considerable number of which have already been reviewed in the *Automobile Engineer*, generally tend to stimulate further developments in this particular field.

The monograph under review, the author's Doctorate thesis, was prepared at Hanover. It was sponsored by the Ministry of Economics and Transport for Lower Saxony, and deals with a problem now well over a century old. Essentially the aim is at ensuring that the brakes of a trailer will maintain the required rate of retardation irrespective of whether the tractor vehicle is empty and the trailer fully laden, or *vice versa*. The obvious approach to an effective solution is to make the drawbar operate the trailer brakes. With this arrangement, the braking force is related to the retardation of the tractor and the mass of the trailer; thus, in theory, adjustment for variations in load is made automatically. A solution along these lines had already been contemplated by George Stephenson, and its possibilities have been continually under review ever since.

Following the introduction of power brakes to motor vehicles, manufacturers have been considering the possibility of regulating the brake force in proportion to the drawbar forces resulting from trailer over-running. However, effective development has been hampered by practical considerations relating to conditions encountered with light tractors and heavy trailers, and during reversing and trailer braking on gradients. In addition, lateral stability of both vehicles, and the fore and aft vibrations initiated by the drawbar springs must be considered before reliable conclusions can be reached as to the possibilities offered by drawbar-controlled brake systems. It is the purpose of the monograph to elucidate these fundamental aspects of the problem.

After a brief introduction to and a discussion of the problem, the author deals with the current position of trailer brakes controlled by drawbar forces, with particular reference to their disadvantages, both with regard to reversing and the frequent adjustments required as a result of the inherent sensitivity of this type of system. Generally, brakes of this type have been found to be useful for agricultural vehicles operating at speeds not exceeding about 10—12 m.p.h. The author concludes that before the arrangement can be considered as suitable for other applications, it will be necessary to solve problems relating to brake application, brake force transmission, application on gradients and when reversing, emergency braking, application when the vehicles are separated, and problems relating to brake control gear between the vehicles. These problems are dealt with in some detail, and the author concludes that all of them can be effectively solved. He considers that the resultant brake arrangement, although more complex than in those at present in general use, will give appreciable improvement so far as overall performance is concerned.

Next, the author discusses the theoretical aspects of power brakes as applied to a vehicle train, including those pertaining to brake application and the fundamental requirements. He also goes on to consider the present state of drawbar-controlled brake design and the possibilities offered by such arrangements. A separate chapter is devoted to fore-and-aft vibrations, which are considered on the basis of a one degree of freedom system. This, together with the preceding chapter, is most thoroughly dealt with; both these chapters cover 32 pages. The theoretical considerations have established the effect of the time required to apply the brakes upon the forces encountered at the drawbar. To verify these findings, extensive tests have been carried out with a number of representative brake systems on a roller test rig. Full scale tests were also carried out with two complete trailers weighing 4·36 and 9·2 tonnes fully laden, and equipped with an hydro-pneumatic brake and a pneumatic brake respectively. The latter, which was of a design especially developed as the result of theoretical considerations and previous rig tests, is described in some detail. While the tests with the hydro-pneumatic brake have not given good results, the drawbar-controlled pneumatic brake has shown a satisfactory performance under all operating conditions.

The main results of the author's investigations are clearly and lucidly summarized, and the monograph concludes with considerations relating to future development and research work concerning drawbar-controlled trailer brakes. The bibliography cites thirty-four references, going back to 1948. This interesting and stimulating monograph shows that even when the fundamental considerations have been clearly appreciated and methods evolved for rapid and reliable evaluation of the effect of the main factors concerned on the overall brake performance, much still remains to be done in the field of trailer brakes. It is thought that the author's work will be valuable in fostering further development, to the benefit of users and designers alike.

Untersuchungen des Dynamischen Verhaltens am Kraftfahrzeugreifen (Investigations of the Dynamic Properties of Tyres). Deutsche Kraftfahrtforschung No. 111.

In German. By Prof. Dr. Ing. P. Koessler and Dr. Ing. R. Menger.
Düsseldorf: VDI-Verlag G.m.b.H. 1958. 11¾×8¼. 20 pp. Price DM 11.80.

In earlier investigations in this field, the numerous tests and analytical investigations relating to tyre performance have been concentrated mainly on steady-state conditions relating to running under practically constant conditions of load and damping forces. Some attempts have been made to simulate dynamic conditions due to impact loads, by imparting shocks to stationary tyres or by loading rotating tyres, but no results of tests to ascertain the performance of tyres running over short obstacles appear to have been made available previously.

This monograph, No. 111, is an abbreviated and slightly modified version of the thesis for the Doctor's degree of the second-named author. It deals with tests, carried out at the Institute for Vehicle Engineering at the Technical High School at Brunswick, to ascertain the dynamic properties of tyres running over short obstacles. The tests were carried out with two wheels running in contact, one above the other. They were run at speeds of 10, 25, 38 and 50 k.p.h., with tyre pressures of 1, 1·5, 2·0 and 2·5 atm, and with wheel loads of 80, 130 and 210 kg. Two types of obstacles were employed: one about 4×4 in, as viewed in plan, and 1 in high, and the other 4×2 in, and 1 in high. The test rig and other equipment used throughout are described in some detail, and the results are plotted in the form of graphs readily understandable even to engineers not familiar with the German language. Particular attention is drawn to the differences in the stiffnesses of the tread surface and the side walls of the tyre and their effect on the performance.

The dynamic lateral stiffness of a tyre was also ascertained by running the wheels at different angles on a drum fitted with obstacle plates 15 mm high. These tests were carried out at tyre pressures varying between 1 and 2·5 atm, speeds of 10, 40 and 70 k.p.h., wheel angles varying between 2 and 8 deg, and loads between 67 and 117 kg. Again, the results are considered in detail and then summarized by means of graphs. The monograph concludes with details of high-speed photographic tests carried out to record the mechanism of tyre deformation as encountered when running over obstacles. Some typical photographs are reproduced to substantiate the authors' conclusions regarding the effect of tyre tread patterns. The bibliography includes forty-nine references. This monograph will be of interest to vehicle and tyre designers; the tests and their results undoubtedly will stimulate further work in this particular field.

The new Thames foundry. View from the melting department end of the plant shows the four cupolas, the telpher system for handling coke and limestone, and in the foreground the two cooling ponds for the plant sluicing system

The Ford "Thames" Foundry

Advanced Techniques, a High Standard of Mechanization, and Exceptional Working Conditions Characterize this New Plant. Production Capacity is 400 tons of Finished Castings Each Day

THIS is a huge plant occupying a 22-acre site and the main building is 1,200 ft long, 180 ft wide, and 70 ft high. Mere size, however, would have been inadequate to meet the foreseeable requirements of the Ford Motor Company's rapidly rising output. As an important part of the Company's expansion programme, the foundry represents a substantial capital investment. It was determined to equip and organize it for flow production, with the maximum degree of mechanization and the use of the latest techniques. Alongside the policy of attaining a very high rate of productivity, equal importance was attached to the minimization of the human effort required in production and the raising of foundry working conditions, as far as practical in view of the nature of the work, to the level of those obtaining in the machine shops.

The foundry, currently "shaking down" to smooth, full-rate production, must be regarded as one of the most advanced in the world. It is unequalled in Europe and is in no way surpassed by the most modern units in America. The aims of the planners would appear to have been well realized in all aspects. Specific output per man-hour, of the particular type and weight of castings produced, is about twice that attained under previous methods of manufacture.

In the main, the foundry produces four-cylinder and six-cylinder engine blocks and heads and the larger castings for agricultural tractors. About 42 different castings are handled and the minimum casting weight will be approximately 30 lb. Production is planned for an output of 400 tons of finished castings per day of two 8-hr shifts.

Sand is brought in by rail to a siding alongside the ancillary building and unloaded, by means of a 35-ton capacity wagon tipper, over a grid to fall into the wet-sand receiving hopper. From the base of this hopper, which is equipped with a vibrator unit, the sand is released to a reciprocating feeder conveyor delivering to a bucket elevator. This lifts the sand to almost roof level and discharges it on to a belt conveyor from which it is ploughed off to charge two storage hoppers and feed two further belt conveyors, at right angles to the first, each feeding three more storage hoppers.

Drying is effected by two Kestner Thermo-Venturi dryers, each designed for a throughput of 12½ tons of sand per hour. The dryer consists of a vertical cylindrical column with, near the lower end, a venturi section. Air heated directly in a combustion chamber in which coke-oven gas is burned is fed by a fan to the base of the column. Wet sand from the storage hoppers is fed down to a point on the column immediately above the narrow throat of the venturi where it meets the heated air travelling upwards at its maximum velocity. The sand particles are entrained in the air and elevated to the parallel section of the column where the moisture is evaporated.

Dry sand is conveyed by the air stream from the top of the column into a Lennox cyclone separator and is conveyed from the base of the separator to the dry storage hoppers. Clean air leaves the separator by ductwork and is discharged to the exhaust stack by the outlet-air fan. Two fans are used in order to obtain a balanced air flow through the system.

Air dampers provided adjacent to the fans can be adjusted

to maintain the optimum flow consistent with a slight negative pressure at the sand inlet feed chute. Once set, further adjustments are not normally necessary unless conditions or material moisture content are substantially changed. The plant is under fully automatic control which serves to regulate the quantity of fuel burned in accordance with the feed rate and moisture content of the sand entering the drying column and thus ensure maximum economy in operation.

From the dry hopper the sand is lifted by four Redler elevators to a Redler conveyor on the roof of the ancillary building. Thence, by a succession of further Redler conveyors, it is transported on a gallery to the roof of the main building where it is divided into two streams. One runs east, to feed two hoppers for the moulding sand make-up and the other west to charge eight hoppers in the core-sand mixing section.

Moulding Sand

The bulk of the sand for moulding is, of course, collected from shake-out and knock-out stations and spillage at the moulding lines. A certain amount of new sand is added to make up for wastage and the whole is "reconditioned" before it is returned to the service hoppers above the moulding machines.

Spillage and shake-out sand is chuted down to belt conveyors on the ground floor. It is then elevated by an inclined belt conveyor to a storage hopper in the floor above. On its way it passes beneath a transverse magnetic belt which lifts out and removes any tramp iron.

The reconditioning plant consists of eight Speedmullors, supplied by Herbert Morris Ltd. These are arranged in two groups of four, each group serving one of the two moulding lines and having a maximum capacity of 200 tons per hour. From the overhead hopper, returned sand is released through pneumatically operated gates to batch-weighing hoppers on each muller. When the scale indicates that the weigh hopper is loaded, the storage hopper gates are closed automatically and the batch of sand is retained until the appropriate time for its delivery to the muller.

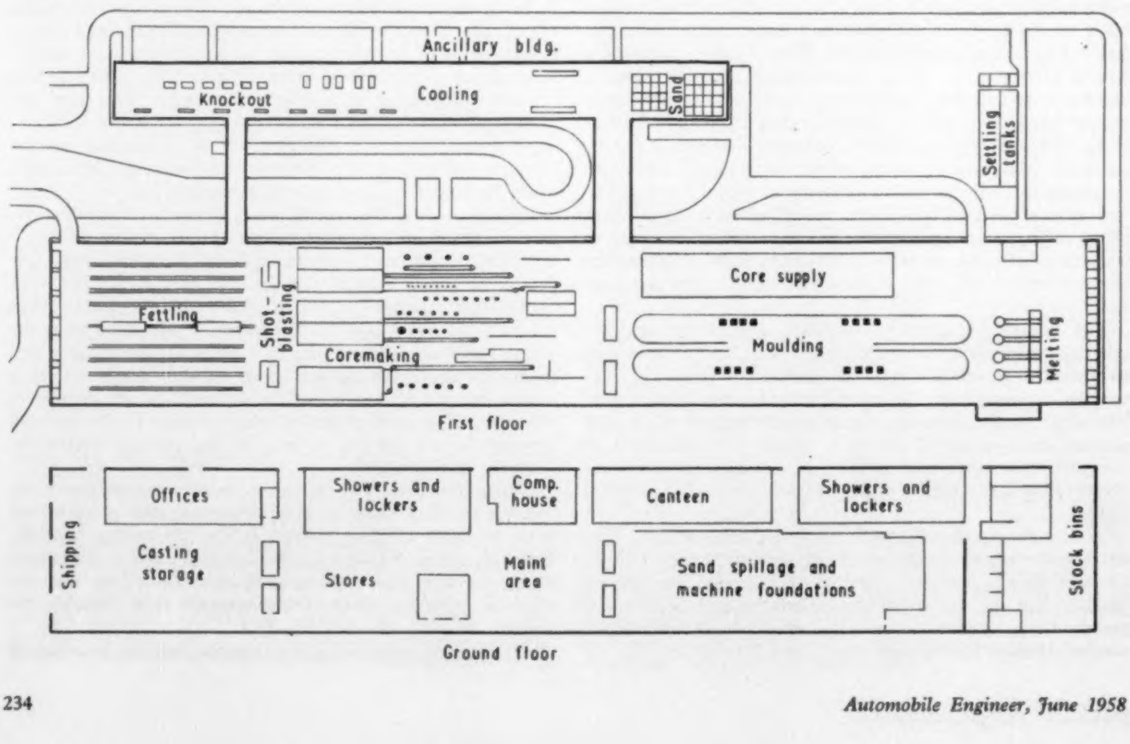
Automatic controls admit an initial quantity of flushing water, followed by a batch of sand and a measured quantity of bonding agents in the form of a slurry. Mulling then starts—the machine has three freely rotating, solid-rubber tyred, planet wheels running at different levels on the wall of the cylindrical casing—and at the end of the preset period the discharge door opens and the sand falls to a belt conveyor. While mulling is proceeding, a further batch of sand is being weighed in readiness for the next cycle. Cycle time per 1-ton batch, including charge and discharge, is 70 seconds.

The conveyor belt under the mullers transfers the sand to an inclined belt that delivers it to the conveyor belt over the line of moulding machine hoppers. From this it is ploughed off as required and new, dry sand joins the surplus sand at the end of the belt for make-up.

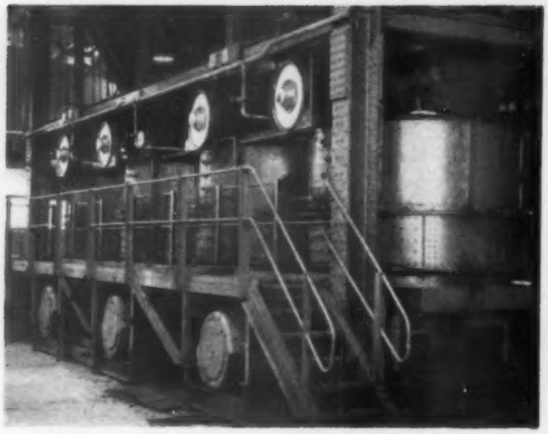
Slurry is prepared in a separate plant on the first floor at one end of the ancillary building. Constituent materials, Fulbond and powdered coal, are received in bulk. The Fulbond arrives on a 15-ton vehicle and is lifted pneumatically, by vehicle equipment and a flexible coupling hose, to a Buell cyclone-type dry separator and from there is passed to four storage hoppers, each holding approximately 60 tons. The separator is claimed to be 99·9 per cent efficient, but the air leaving the unit is passed through an Acme wet separator before it is vented to atmosphere. Material arrested by the wet separator is passed to the plant sluicing system.

Coal powder is in 15 cwt containers, eight constituting a lorry load. The container is lifted by a 30 cwt lift and travel hoist on a monorail track over four hoppers, each having a capacity of about 40 tons. When a container is lowered on to a vibrating platform on a hopper, a conical valve member sealing the entry is opened automatically. A flat slide valve in the container is opened and the contents are discharged.

Diagrammatic layout of the Thames foundry. All the major equipment is installed on the first floor of the 1,200 ft × 180 ft main building



Kestner T.V. pneumatic sand dryers and elevators



Battery of "Speedmullors" for moulding sand conditioning

Graviner detection and suppression equipment is used throughout the installation against the hazards of fire or explosion. Each hopper is fitted with seven high-discharge rate bottles of chlorobromomethane. These come into operation should the pressure rise faster than 0·5 lb/in^2/sec or by a total of 5 lb/in^2 static. There is also a thermally responsive switch, operative on a temperature rise of the order of 35 deg C. Explosion vents, opening directly to a large-section stack, are covered by aluminium foil and weighted by a glass fibre reinforced plastics panel.

To mix the slurry, metered quantities of the dry materials are fed into a 37-ft Riley vibrating conveyor and then chuted into the water in a propeller-type mixer. Approximately 130 gal water, 350 lb coal powder and 360 lb Fulbond are required for a 200 gal mix. From the mixer the slurry passes to a storage tank and is then conveyed by a Mono pump through a 2 in ring main to the Speedmullers in the main building. All controls, grouped on a panel in the ancillary building, are interlocked for sequence. Mixers, pumps and mains are duplicated and separately controlled.

Metering of slurry for the Speedmullor is effected by timing the opening of a Saunders-Crosby air-operated diaphragm on impulse received from the Speedmullor sequence panel. From one to three gallons of slurry may be required for a 2,000 lb mix in the muller.

Core sand

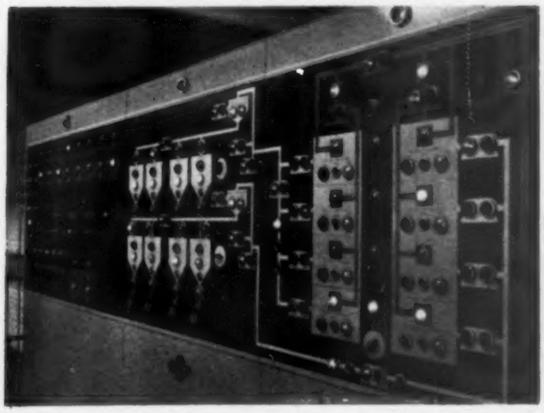
Initial planning indicated that at least 350 tons of bonded core sand would be required per working day of two 8-hour shifts, and that to meet all contingencies production capacity should be capable of carrying overload surges up to 25 per cent in excess. It followed that for the proportioning and preparation of an individual mix of one ton, a period slightly less than three minutes was all that could be allowed.

Ten differently proportioned basic mixes had to be catered for and, to meet possible variation in the physical properties of the ingredients, each mix had to be capable of rapid, detail adjustment. It was stipulated that the mix should be accurate to within 1 per cent of specification. These aspects of production were to be taken out of the hands of plant operators and placed under the control of a qualified chemist. Finally, it was necessary to convey the prepared mix to a selected work station in the core-blowing department at speeds in excess of 100 ft/sec.

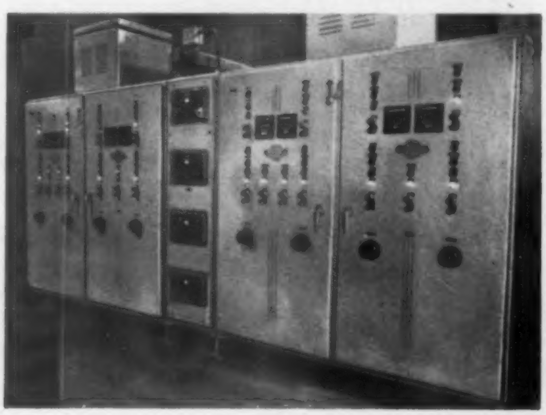
The automatic proportioning equipment installed in the Thames foundry successfully meets all these requirements, and is probably the most technically advanced aggregate of its type in the world. In conception, design and construction it is the result of collaboration between the Ford organization and the Sinex Engineering Co. Ltd.

It consists of four Sinex batch-weighing groups to handle

Mimic panel for new sand distribution control



Slurry plant control panel. Explosion suppression control in centre



the proportioning of the dry sands and additives. These materials are brought to the plant by Redler conveyors and held in storage hoppers compartmented to contain two types of sand and three additives. Two scales with weigh hoppers are provided, for each of the four groups, one for the sand and the other for the additives. On each group, three metering pumps are time-cycled with the weighing equipment to deal with the liquids—water and two oils. Mixing is effected in August-Simpson Mix-Mullers, and the bonded sand is delivered to the selected core-blowing machine by a Crane Turbo-drive pneumatic conveying system.

Selection of composition formula is by means of the Oerlikon punched-card system. Ten basic mixes are interpreted by punched cards and variation of any mix is obtained, if necessary, by altering the pattern of the card punching. Each mix is designated by a single letter and each punched card is similarly identified.

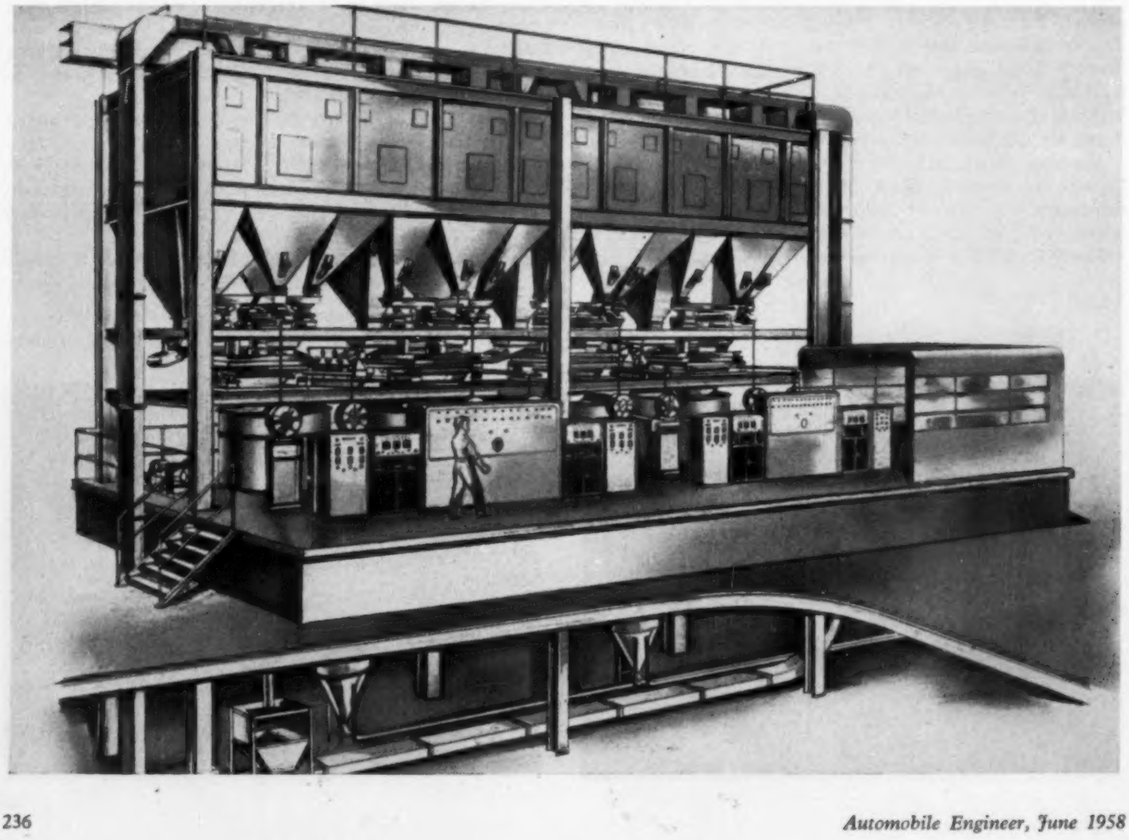
All control equipment is grouped alongside the plant and comprises three main panels to each of the four units. In addition, Graviner detection equipment is installed for the suppression of any explosion inside the hoppers. Each control group consists of a mixing control panel, an Oerlikon control panel and a Crane Turbo-drive operating and indicating panel (mimic panel) for routing of the mixed sand. On the first panel are monitor lamps to indicate the progress of the mix, four process timers, and start, stop and re-set controls. The Oerlikon panel carries the controls by which the operational sequence is initiated and controlled and with which all the timing sequences are interlocked. A drawer beneath the panel houses the holder for the selected punched card and the start button. On the mimic panel is indicated the supply requirements of the core-blowing machines. The operator is made aware of the mix awaiting delivery, the mixing progress, and the batch being proportioned, and is also able to select the correct delivery point for a given mix. Lamps indicate the condition of the Turbo-drive equipment, whether "Available" or "In use," and a 14-way switch enables the desired delivery outlet to be selected.

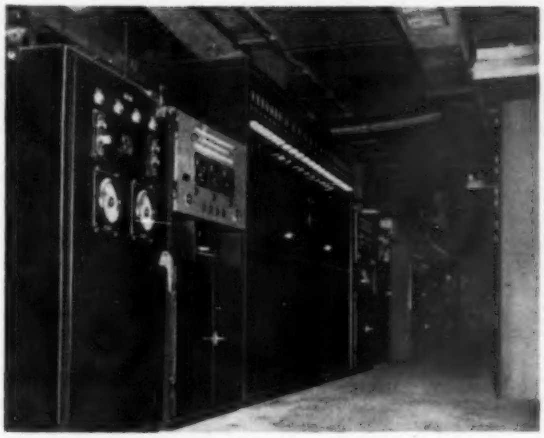
The automatic operational cycle is initiated by insertion of the punched card in the drawer of the Oerlikon cabinet. A monitor lamp bearing a letter, and a group of numbered lamps in another row, are illuminated to show the selected mix and the individual ingredients of the mix. This numbered group indicates the progress of the weighing sequence. On pressing the start button a red "Weigh in progress" lamp is illuminated and the weighing sequence commences. The punched card passes under electro-sensitive feelers which transmit impulses to preselector units in the scale dial heads and to the revolution counters of the liquid metering pumps of the Sinex batch-weighing system. These impulses preset the quantity of the first ingredient in the dry and liquid groups. The cycle is timed so that weighing of the dry materials and the dry additives starts simultaneously. Delivery of the metered liquid constituents to the Mix-Muller is delayed until after the dry mix has commenced.

The weighing cycle proceeds as follows:

1. The vibratory feeder for the bulk materials is started by an impulse from the Oerlikon controller and commences delivery, at a high rate, of the first ingredient—usually Aylesford sand—to the weigh hopper. As the weight approaches the pre-set value, the detector actuated from the scale pointer operates relays which change over from fast rate to slow rate on the feeder, reducing the delivery to a trickle. Immediately the correct weight has been delivered,

Diagrammatic impression of the Sinex automatic proportioning plant for core sand. Below are the two "Turbo-drive" sand delivery units





Control room of the core sand proportioning plant

Sand feeders and weigh hopper

a further relay operates to break the power supply to the feeder and to extinguish the appropriate "Weigh in progress" lamp on the panel.

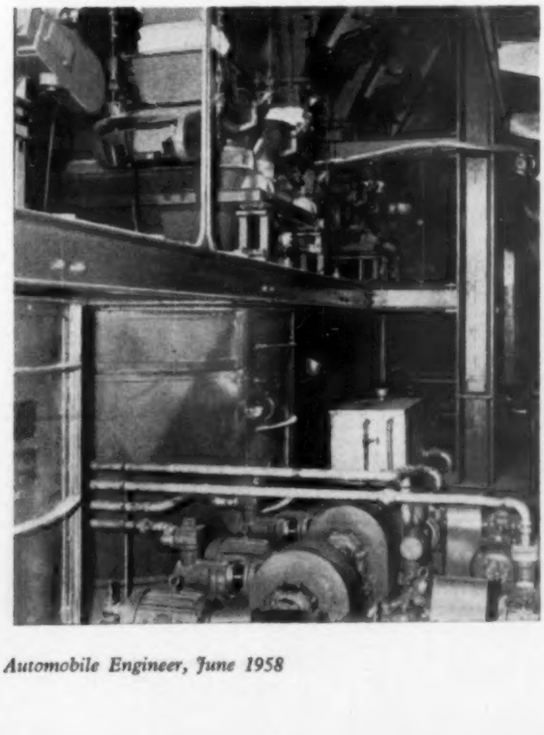
2. A signal from the controller now sums the weight of the first and the second ingredients—usually Garside sand—and pre-sets the required total weight at the scale dial head. Sand from the Garside container is then vibrated to the weigh hopper and controlled to the final value as before.

3. In parallel with these operations, the additives—flour, bentonite and, in some instances, iron oxide—are similarly weighed and the associated "Weigh in progress" lights are extinguished. If at this point the sand weighing cycle is completed, the bond weigh hopper discharges its contents into the sand weigh hopper. The red "Weigh in progress" lamp is then extinguished and the green "Held" lamp illuminated.

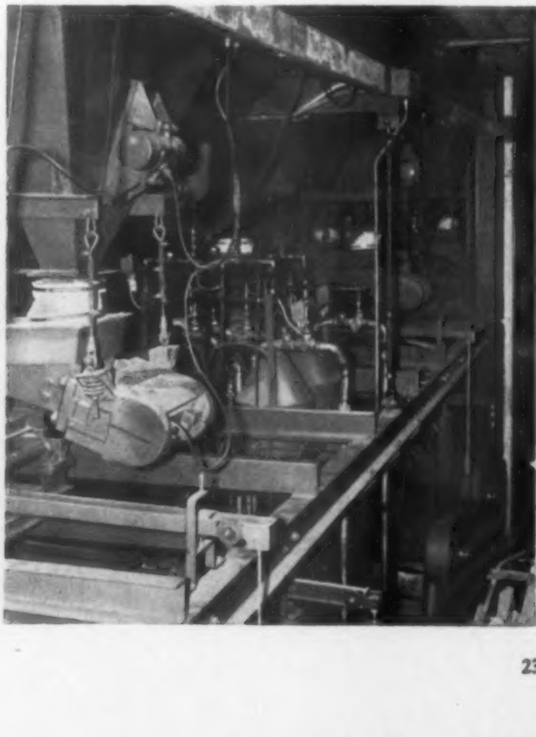
While the weighing cycle is proceeding, the metering pumps transfer pre-set volumes of water and two oils from the storage tanks to two blow tanks. When the start button on the mixer control panel is depressed, the dry materials are discharged into the muller and the mixing cycle is started. After a period of 10 seconds the blow tanks discharge the liquid additives, under air pressure, into the muller. The green "Held" light then goes out and a new weighing cycle can be started.

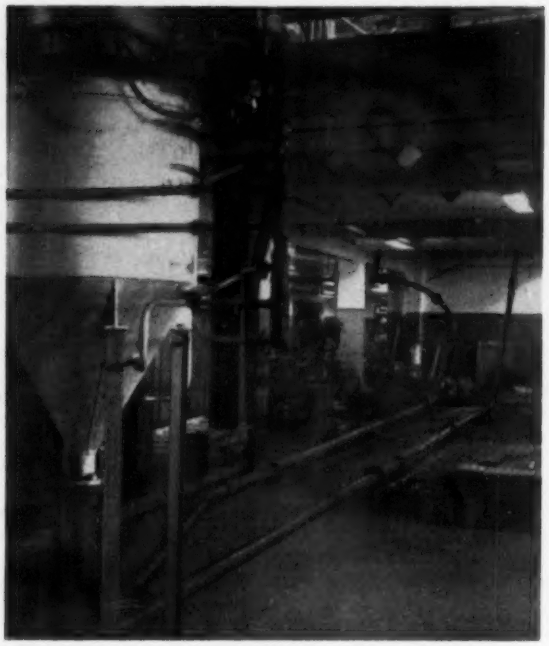
The final mixing sequence is timed and monitored by the mix timer. Orange lights are provided on the mixer panel to indicate that dry materials, oil and water are directed to the mixer. These are illuminated in succession to show the completion of each operation, and each cycle is timed on the appropriate timer. When the mulling is completed the mix is discharged automatically to the Turbo-drive system, the delivery being indicated by the fourth orange lamp and timed by the fourth timer.

Sand feeders, weigh hoppers, "Mix-Mullers" and liquid pumps



Bond ingredients feeders and liquid blow tanks





Crane "Turbo-drive" unit for pneumatic delivery of core sand

At this stage the plant holds a finished mix in the Turbo-drive equipment awaiting delivery, another mix is in progress, and a further batch is being proportioned. The operator then observes the mimic panel where the supply requirements of the core-blowing machines are indicated by the illumination of numbered and lettered lamps. The number of the light in the top row indicates the core machine requiring material and the letter indicates the specific mix required. These lights are actuated by Sinex diaphragm-type bin-level relays in the core-blower storage hoppers. They operate when the sand in a hopper falls below a given level. Memory lights in the bottom row of lamps on the mimic panel are lettered to show the mix held in the Turbo-drive unit. A mix is supplied to the appropriate core blower by selection of the machine number on the 14-way switch on the panel. Selection of the number illuminates the equivalent "Selected station" lamp in the middle row. Depression of the "Blow" button will then deliver the charge to the core-blowing machine and the next mix can be completed.

For test purposes or in the event of any failure or malfunction of the automatic system, operations can be conducted by manual control. On both the Oerlikon control panel and the mix control panel are appropriate switches for this purpose.

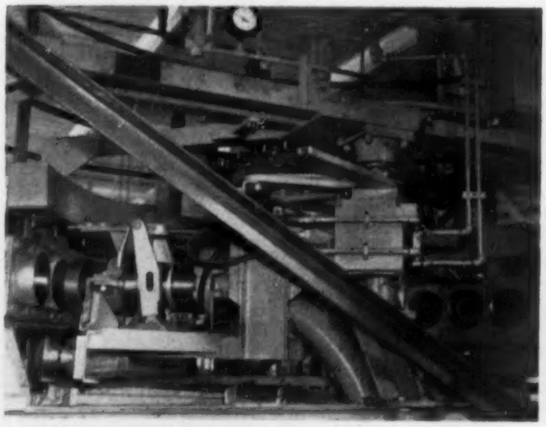
Supplied by August's Ltd., the Mix-Mullers are of the Simpson type, with a mixer 7 ft diameter × 4 ft high and driven by a 40 h.p. motor. The outstanding feature of this type is the method of mounting the mullers on bell cranks pivoting on the vertical shaft and loaded by a single compression spring carried between the arms of the bell cranks. By this means a high muller pressure—up to 2,000 lb in these machines having a batch capacity of 2,000 lb—becomes possible with relatively light mullers and, consequently, a minimum of muller inertia. The spring is enclosed in a telescoping casing and the applied load is, of course, capable of adjustment.

Pairs of Mix-Mullers each capable of delivering a 2,000 lb charge of sand every three minutes, feed a Crane Turbo-drive unit. This consists of a vertical cylindrical casing with a conical base section. The mixed sand is admitted through a gate in the top cover, which is reclosed automatically when the "Blow" button on the control panel is depressed. Pressure air is first admitted by way of tangential jets in the conical section in order to promote a swirling motion of the sand about the outlet orifice in the base and then air at a pressure of 60 lb/in^2 is admitted to the head of the casing by a 2 in diameter conduit. The complete charge is propelled along a main at a velocity of more than 100 ft/sec to the 14-way switching station, already pre-set from the control panel, and thence to the hopper over the selected core-blowing machine.

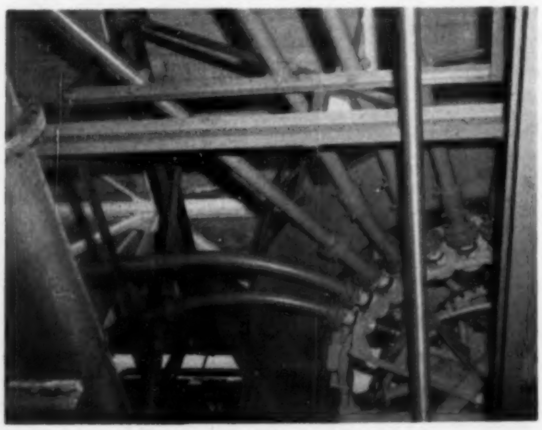
At the switching station, the sand main connects with a telescoping conduit mounted on a radial arm that can be swung through an arc in a horizontal plane. The arm is provided with an indexing mechanism to align the conduit precisely with any of fourteen internally coned sockets arranged in a semicircular framing. Externally, pipe lines are run from the sockets to the service hoppers above the core-blowing machines. Remotely controlled, from the 14-way switch on the mimic panel, the radial arm is automatically indexed to the selected line and the externally coned end of the telescoping conduit is moved to seat firmly under pressure in the appropriate socket.

There are two Turbo-drive units and two 14-way switching stations. On one of these, nine lines are furnished with 2-way switches, thus enabling a total of 23 hoppers to be

Fourteen-way selector junction for core sand delivery, interior



Fourteen-way selector junction for core sand delivery, exterior



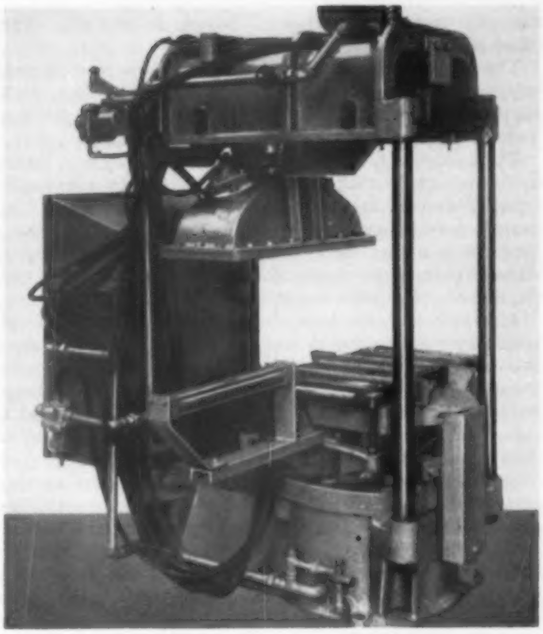
served. In these switches, short sections of straight-through and divergent pipes are arranged on a carriage. When a changeover is operated, the carriage is first lifted to break the angled joint faces, then traversed to bring the other pipe into position, and finally lowered to establish the new connection. These two pneumatic delivery systems are the only examples of their type outside the U.S.A.

In all, the proportioning plant feeds 37 hoppers serving 45 core blowers and core shooters. Manual labour is eliminated in the handling of raw materials, in mixing, and in the distributed delivery of the bonded mixture. Plant operators can exercise no influence on the proportioning of the various mixes and consequently homogeneity is obtained in each individual mix and consistency is maintained throughout long production runs. It is noteworthy that for a plant with such a high throughput only four operators are needed. One unloads and dries the sand, one distributes sand to core and mould departments, two control the Sinex proportioning plant.

Core making

Occupying an approximately central area of the main building, the core making department is located between the moulding lines and the fettling lines. All cores are made on semi-automatic machines, 39 core blowers and 6 core shooters. Outstanding machines are four No. 300 high-speed, central blow-head, twin-station units supplied by Foundry Equipment Ltd. These are used for the large, intricate cylinder block cores. At full capacity each of these twin-station machines can produce approximately 120 cores per hour. The maximum weight of the cores produced is 90 lb, considerably less than the weight of cores blown on the smaller F.E. No. 220/530 machines also installed in the department. This is accounted for by the more intricate character of the cores and the fact that the core boxes are split mechanically in four directions so that barrel cores can be produced.

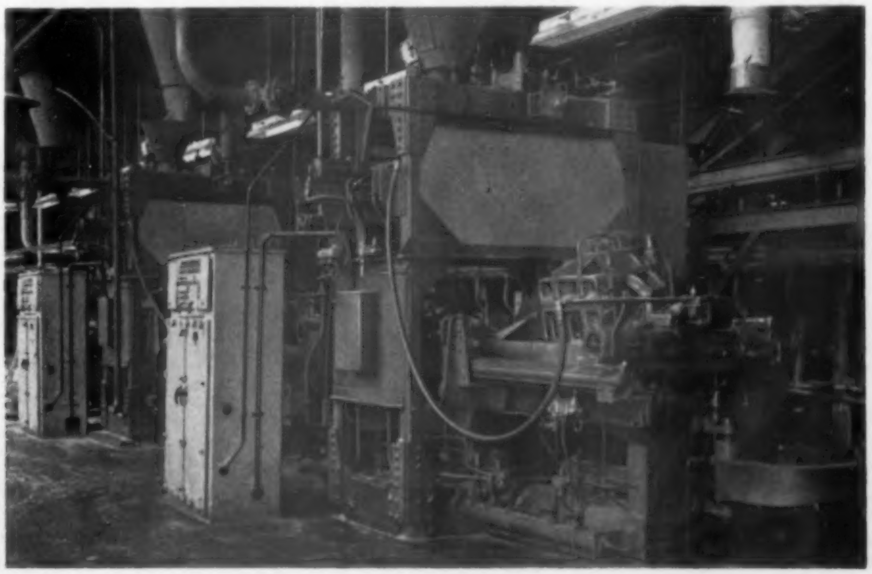
A battery of five 220/530 machines are installed. Each consists essentially of five units—core blower, roll-over, transfer, push out, and lift—mechanically combined and linked by air and electrical circuits. Operation is electro-pneumatic and all movements are interlocked for correct sequence. Various movements require adjustable time delays and the circuits for these and the interlocking system



Osborn-Jackman core-blowing machine

are housed in a control cabinet remote from the machine. Push buttons and sequence switches on the front of this cabinet enable each movement of the machine to be tested individually. For production control certain of these buttons are duplicated on a small panel on the front of the machine, convenient for the operator.

Two core boxes are employed, being mounted one on the top and one on the underside of the roll-over table. While the top box is being used for blowing a core, a previously made core in the inverted bottom box is being stripped. When working on a continuous cycle, operation stops when the top core box has been blown and transferred out to the roll-over table. In this position, a dryer plate is placed over



Foundry Equipment two-station machine for cylinder block cores

the core and the "Roll-over" button is pressed. This initiates the next complete cycle.

The dryer plate is clamped and the table inverts, thus bringing to the top the previously stripped core box, while the newly blown core box rolls over to the stripping position. The core, of course, is retained by the dryer plate.

The top core box is transferred into the blower, where it is raised and forced against the blow head by a hydraulic cylinder working in conjunction with a booster unit. This pre-set booster pressure initiates the blow. Air under pressure in a cast steel reservoir at the machine head is released to force the charge of sand carried in the blow head, through the blow plate and into the core box.

After blowing for a pre-set period the air is cut off, residual pressure released, and the core box is lowered away from the blow plate. The blow head then traverses horizontally to receive a new charge of sand from a storage hopper above the machine head. While the blow head is being recharged, the blown core box is transferred out to the roll-over table.

Simultaneously with the foregoing operations, the inverted core on the underside of the table is being stripped. The draw saddle rises to the dryer plate, opens the clamps, starts the box vibrators, and commences its slow downward strip stroke. After a suitable length of travel, the strip motion changes from slow to fast rate to complete the operation. A pusher then moves the core laterally on its dryer plate to a position above the lift platform. This device is not included in the automatic cycle, but is operated by a foot valve to raise the core, on the dryer plate, to a convenient level for handling. However, operation of this valve also serves to reset the automatic air circuit for the roll-over. On release of the valve the lift platform returns to its lower station.

On the control cabinet is a selector switch for "Continuous" or "Single" cycle. If "Single" is selected the empty box will not automatically be transferred to the blower after the table has rolled over. This provides opportunity for the operator to replace loose inserts in the box, and the machine cycle is then re-initiated by depression of the "Start" button. Emergency stop buttons that exhaust all air from the machine and cut off the electrical supply are provided on both the control cabinet and the machine panel. An electrical failure will de-energize the solenoid of the mains air valve and stop the machine.

These machines can produce cores to overall dimensions of 36 in$\times 22\frac{1}{2}$ in$\times 11\frac{1}{2}$ in deep up to a maximum weight of 125 lb. Minimum operational cycle time is 15 sec and at this high production rate the free air consumption, at 100 lb/in^2 pressure, is 164 ft^3/min.

A large number of Osborn 193A and 194A core-blowing machines are installed. These machines, supplied by J. W. Jackman & Co. Ltd., are pneumatically operated and controlled to give a fully automatic blowing cycle. The operator positions the core box on the lift table and pulls the operating handle. In automatic sequence, the machine clamps the box up to the blow plate, blows the core, exhausts at the termination of the blow, unclamps the box, and finally ejects the box on to a conveyor. The sand reservoir moves to the "Fill" position, receives a new charge from the sand hopper, and returns to the "Blow" position.

Loading of the core box into the machine, and unloading, is facilitated by the provision of rollers on the lift table. These rollers sink below the level of the table surface when the box is clamped preparatory to blowing. Boxes of a wide range of heights may be used since the clamp piston has a maximum stroke of 10 in. This feature enables horizontally divided boxes to be used, with the cope secured to the blow plate. The core is stripped from the cope while on the machine, thus facilitating the placing of the dryer plate and the stripping of the core from the drag. Miminum cycle time on these machines is 7 seconds.

Hansberg Coreshooters are used for certain cores requiring a relatively stiffer sand mix. These machines are of Italian origin and embody the principle of "shooting" a compacted sand mass into the core box instead of injecting it in the manner of core-blowing machines. The major advantage claimed for the shoot method is that compressed air does not enter the core box during the filling process and, consequently, the need for venting the core box is greatly reduced. Furthermore, the sand-blasting effect of blown sand on the core box is largely eliminated, and a more densely rammed core is obtained.

The machine is arranged for semi-automatic operation, with oil and pneumatic actuation. Control is effected by two levers on the machine head. A lever on the left controls the vertical traverse of the table and pre-sets it to a convenient height to suit the depth of the core box in use. The right-hand lever controls four sequential operations; closure of the sand shutter, closure of the core box clamp, elevation of the table, and shooting of the core.

From the machines, the cores are transferred by the operators to platform hangers on an overhead chain-link conveyor which carries them through the baking ovens. The baking installation comprises a battery of five ovens to the design of the Foundry Equipment Co., of Cleveland,

Foundry Equipment core blower with roll-over and lift

Joint faces of cores are finished on grinding machines

Ohio, and supplied by Matthews and Yates Ltd. Hot air, directly heated in a coke-oven gas furnace, is circulated by fans through ducts in the framing and enters the oven by louvres in the side panels. The conveyor loops backwards and forwards in the oven, entering and leaving by the same end. A final section is operated as a cooling zone, and when the baked cores emerge into the shop they are handleable.

Operating temperature is 450 deg F and baking time is varied in accordance with the cross-sectional area of the cores. Two hours is sufficient for the relatively smaller cores, but up to 2 hr 36 min may be required for larger cores. All the ovens—four are of the 4-pass type and one 6-pass—are elevated from the shop floor to provide a storage area underneath for finished cores. All cores are baked at least 24 hours before they are used in the mould.

After leaving the baking oven, cores are inspected and any minor rectification is effected, if necessary. Such part of the core that is contacted by molten metal is then coated, by dipping, in a plumbago or a Charnotte wash. Washed cores are dried in three horizontal core-wash ovens. Finally, the dried core is finished on a core-grinding machine to precise height or length for jigging.

There are nine of the machines in two types, both of American manufacture. One has two spaced, overlapping abrasive wheels, with their spindles lying in parallel planes arranged at an acute included angle, to produce an obtuse-angled locating face on the core. The carriage of this machine operates on a pendulum cycle, one core being ground while the other fixture is unloaded and reloaded. A flat locating face is ground on the cores by the other type of machine. This resembles a conventional surface grinder, having a large diameter annular abrasive wheel on a vertical spindle and a rotating table carrying two fixtures. Again, one core is ground while the other fixture is unloaded and reloaded.

Finished cores are stacked on stillage racks of an unusual type. The rectangular frame is arranged to accommodate a number of detachable shelf units that can be positioned at suitable vertical spacings. Each shelf is hingedly attached at its rear edge and latched at the front, and tension springs at each side connect the front of the shelf to the rear framing. Loading is from the lower shelf upwards, with the empty shelves retracted by the springs to give access, and as each shelf is filled the one above is brought down to position and latched. This procedure, reversed when unloading, of course, eases the labour of loading or unloading and minimizes the possibility of damaging the cores. Stillages are placed in storage and transferred to the moulding lines by lift trucks.

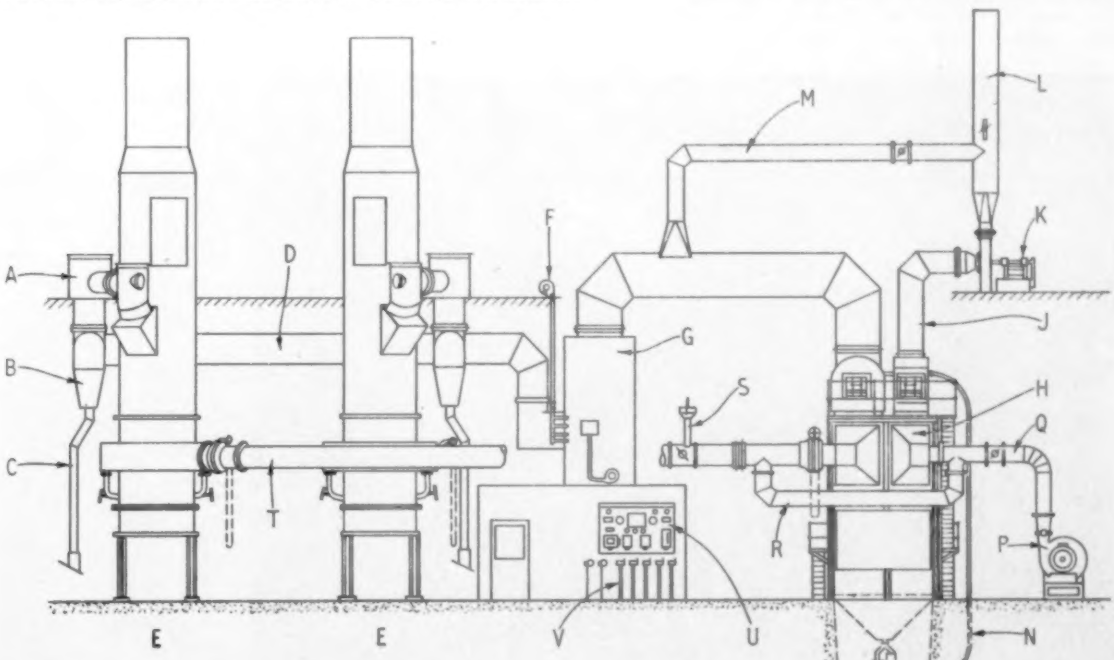
Melting

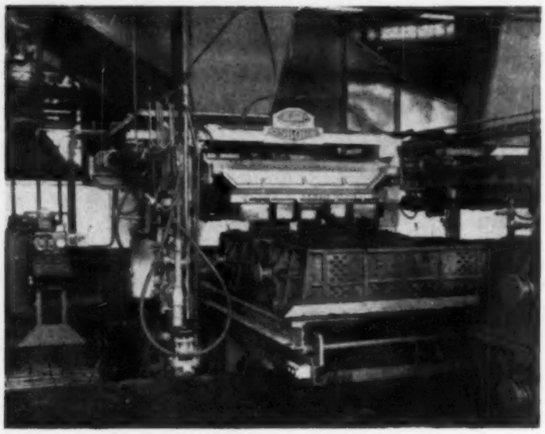
Pigs and coke are brought in from the Ford Dagenham blast furnace and coke ovens by the Company's own rail system, operating with diesel locos. The metallics—pigs, scrap steel, and back-scrap—are assembled in an enclosed dock and lifted as required to the skip-loading platform by two 6-ton Babcock and Wilcox overhead cranes each equipped with an electromagnet. Care is taken to prevent the coke being broken down in transit. It is transported in special containers which are lifted from the rail wagons and discharged into storage hoppers above the skip-loading platform by a telpher system. Limestone is handled by the same method.

At the skip-loading platform the metallics are fed in

Diagrammatic arrangement of typical Cupodal hot-blast cupola installation

A stack-gas damper; B dust collector; C dust chute; D stack-gas main; E refractory-lined, water-cooled cupolas; F combustion-air fan; G combustion chamber; H recuperator; J waste-gas main; K exhaust fan; L exhaust stack; M waste-gas recirculation; N shot-cleaning equipment; P cold-blast fan; Q cold-blast main; R recuperator by-pass; S hot-blast valve and vent; T hot-blast main; U control panel; V remote controls for valves and dampers





Osborn automatic-cycle moulding machine

sequence to a weigh hopper, indicating the weights on a large diameter dial visible to both the crane driver and the skip operator. When the metallics are received in the skip, it moves to a second station and measured quantities of coke and limestone from another weigh hopper are added to the charge. The skip is then elevated to the charging platform, the charge is unloaded into the cupola, and the skip returned to the loading platform on an automatic cycle.

The four cupolas are of the hot-blast type, 108 in diameter and water cooled around the melting zone. Each has its own skip charger, and each pair is served by a hot-blast installation. Cupolas are operated alternately in pairs; while two are melting two are being rested for lining repairs and general maintenance. Individual melting capacity is 30 tons per hour. Each hot-blast unit, built by Cupodel Ltd., is designed to supply air at the rate of 16,000 ft^3/min at a blast temperature of 500 deg C. These are the largest units to date installed in the United Kingdom.

An exhaust fan driven by a 150 h.p. motor extracts the cupola gases through three offtakes located a short distance below the top of the cupola burden. The gases, at from 400 to 600 deg C, pass through a centrifugal dust extractor before reaching the cylindrical, cyclone-type combustion chamber where they are burned with air supplied by a separate fan. Leaving the combustion chamber at a temperature of more than 1,000 deg C, the gases are drawn over four banks of cast steel and cast iron ribbed tubes in a recuperator. Here they give up heat to the blast air flowing through the tubes. Leaving the recuperator at about 500 deg C, the gases pass through the exhaust fan and are exhausted to atmosphere by way of a stack in which is located a valve controlling the volume drawn through the system. Some gas from the exhaust stack is recirculated to lower and control the temperature of the gas to 800 to 900 deg C before entering the recuperator.

An interesting feature of the recuperator is the Swedish Broman Ekström mechanical shot-cleaning equipment for the tubes. Without interruption of operation, shot from the base of the recuperator is elevated to the top of the unit by high-pressure air and distributed over the upper banks of tubes. In falling through upper and lower banks, the shot effectively dislodges dust collected on the tubes. Shot and dust fall to the base, the dust is separated out, and the shot is collected for recirculation. At the Ford installation the equipment is operated for two 30-minute periods each shift.

Blast air is supplied by a Keith Blackman high-pressure centrifugal fan driven by a 275 h.p. motor and, after heating in the recuperator, is conducted through an insulated main and wind belt to the cupola tuyeres. A high wind-belt pressure of the order of 65 in w.g. is employed. By means of a recuperator by-pass main—closed during normal operation—the cupola can be operated on cold blast if necessary. In the event of a temporary interruption of melting, a single push-button control can shut off the hot blast to the cupola and simultaneously open a vent to allow cold air to pass through the recuperator and prevent overheating of the tubes. For preheating, a large Gako coke-oven gas burner with electric ignition and automatic flame-failure equipment is

Monometer hot-metal receivers, each holding up to eight tons of metal at pouring temperature, ensure a continuous supply of metal from the cupolas to the moulding lines

Multiple-core assembly jig

Multiple-core lifting jig

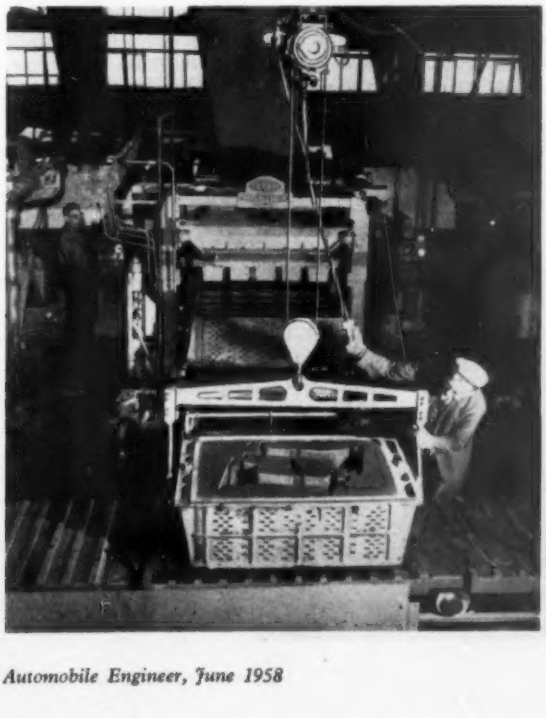
provided in the combustion chamber. Coke-oven gas is used normally only for a short time at the start of each week's melting programme, but it can be used to augment the cupola gas if necessary during periods of low-rate operation.

Each hot-blast installation is fully instrumented by Evershed and Vignoles Ltd. A central control panel for each plant has temperature, draught, and pressure instruments for gas and air flow; automatic controls maintain steady recuperator and blast temperatures; all control valves are motorized and operated from push-buttons and position indicators on the panel. The cupola blast is controlled automatically by Foxboro Yoxall Ltd. air-weight equipment. A recorder shows the height of the charges in the cupola.

At each cupola is a Monometer stationary, hot-metal receiver having a capacity of eight tons. It is refractory lined and equipped with a suspended roof in four sections. For heating up from cold or maintaining metal temperature during meal breaks or other interruptions of operation, the receiver is fired by coke-oven gas. The burners are located at one end of the receiver and the flame is directed over the surface of the metal. Exhaust gases are used to preheat the incoming air to the burners. Gas firing is unnecessary during the run-through of normal operation. At the opposite end is a hopper to receive the metal flowing from the cupola, without interruption when the receiver is tilted to fill a ladle.

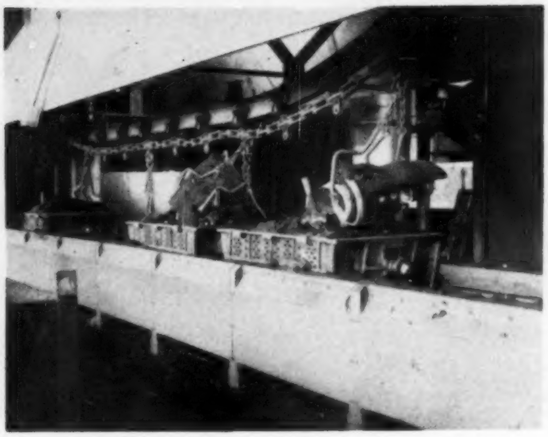
In the cupola launder is a weir and the slag layer flows off and falls into a trough of running water. The slag, on quenching, breaks up into granules and is carried away by the plant sluicing system for disposal. Thus a supply of slag-free metal at pouring temperature—1,450 to 1,500 deg C —is maintained at all times for the intermittent feeding of ladles for the conveyor system of casting. The receiver is mounted to tilt on rollers carried on ball-bearing plummer blocks. Tilting gear is fully mechanized, with push-button control, supplemented with manual gear for precise control.

Pouring equipment comprises ten barrel-type ladles of 2,000 lb capacity, suspended from electric hoisting and towing units, for metal conveying and pouring the larger castings and four 1,000 lb ladles for smaller castings. To meet the contingency of a temporary hold-up on the moulding line, a pig-cast machine with a capacity of 20 ton/hr is available to handle surplus metal from the cupola.



Left: Transfer of drag mould from machine to mould conveyor

Below: Pouring line with synchronized ladle conveyor line



Casting drag-out by cooling conveyor chain

Moulding

Moulding is carried out on two 800 ft, continuous loop, Acme pallet conveyor lines, encircling eight semi-automatic moulding machines, four for drag flasks and four for cope flasks. The flasks are of a large, standard size, each 46 in × 31 in × 16 in deep, and have trunnion ends for lifting and turn-over operations. Empty flasks are brought to the moulding machines by return conveyors inside the main conveyor loop.

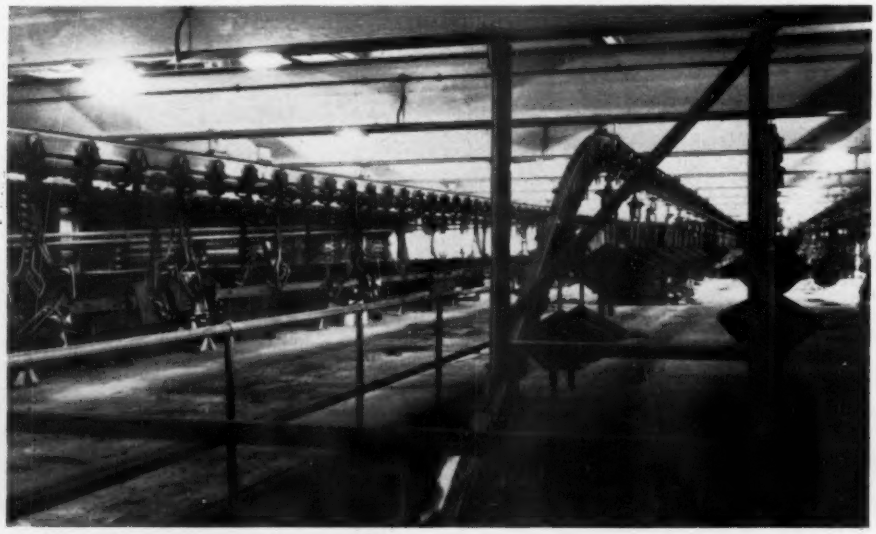
The Osborn 1236J moulding machines, the largest of their type, and each weighing over 20 tons, were built by J. W. Jackman and Co. Ltd., to the design of the Osborn Manufacturing Co., of Cleveland, Ohio. They are equipped for automatic or semi-automatic cycle operation initiated by the operator and can complete a cycle in 22 seconds. Each machine pulls in an empty flask as a completed flask is pushed out. This is effected by a latch on an overhead carriage carrying the sand measuring box and the squeeze head, and the following operations occur sequentially.

The flask is lowered on to the pattern plate secured to the machine table and is filled with a predetermined quantity of sand on the automatic opening of louvres in the base of the measuring box. It is then jolted for a pre-set number of jolts to settle the sand firmly against the pattern plate and excess sand is strickled off by means of a bar as the squeeze head moves into position over the machine table. Simultaneously, the measuring box returns to the "Fill" position where it is recharged from the overhead service hopper, and the run-in latches engage on the next empty flask.

With the squeeze head in position, the table is raised by a 36 in diameter squeeze piston, and the sand in the flask is subjected to a pressure of more than 70,000 lb to further consolidate it. At the same time, the draw frames, fitted with rollers, rise to the flask run-in/run-out level. The table, pattern, and flask are then lowered. The draw frame intercepts the flask, a vibrator mounted on the pattern is energized to free the pattern from the sand face, and the pattern is stripped down out of the mould. The squeeze head then moves clear of the machine table, pushing out the completed mould to the run-out stand and bringing the filled measuring head and the next empty flask over the table to complete the cycle.

In the Ford foundry, a semi-automatic cycle is currently employed. The machine stops after the flask has been jolted and strickled off. Two buttons must be depressed simultaneously to re-start the cycle at the squeeze operation, thus ensuring that both hands of the operator are engaged and any risk of being trapped in the squeeze is obviated. The completed drag flask is turned over and transferred to the main conveyor on the lift-and-travel air hoist. Cope flasks do not require to be turned over, but are lifted out and lowered directly to the drag on the conveyor, after the cores have been fitted to the mould, of course. An item of interest on the cope is that no separate pouring head mould needs to be added. There is a sufficient height of sand in the deep flask to enable this to be formed as a depression in the sand by means of a suitable pattern attached to the squeeze head.

In the case of complicated coring, as for an engine cylinder block, the individual cores are taken from the stillage racks, already referred to, and assembled on a transportable jig placed alongside the mould conveyor. Long guiding dowels are inserted in the jig base and then a lifting jig suspended on an air hoist is lowered over these. When in position, pneumatically operated fingers engage under the core assembly and it is lifted clear of the assembly jig and transferred to a position over the mould conveyor. The guide dowels are inserted in the drag flask, the core assembly is lowered over the dowels into the mould, the latching fingers retracted, and the lifting jig withdrawn.



Castings and back-scrap conveyors in a gallery between the buildings

Cope and drag are locked together by knock-on clamps before reaching the pouring section of the conveyor line, just prior to the loop in front of the cupolas. A King monorail conveyor system is provided for handling the ladles at a speed synchronized with that of the mould line. The operator fills the ladle from the hot metal container at the cupola and the self-propelled, two-speed hoist unit transports it on the monorail to the start of the pouring section. Here it is adjusted to align with a mould and then latched on to a chain running parallel to the mould conveyor and at the same speed. The suspended control box has buttons for forward travel, fast or slow; reverse travel, fast or slow; latches, engage or disengage; and stop. Operating conditions in the pouring section are particularly good. The area is well lighted, fresh air is brought in by an overhead trunk, and heat and fumes are carried off by a large-section ducting with the intake angled over the pouring line.

The metal solidifies while travelling round the loop and starting down the parallel line in the opposite direction. Clamps are knocked off and approximately half-way down the line the cope flask is lifted, vibrated to clear of sand, and placed on a roller track for return to the moulding machines. Headers and risers are knocked off the casting and carried away by the back-scrap conveyor to the ancillary building. The drag continues through a cooling and fume-extracting tunnel and, after traversing the end loop, enters the drag-out section. Castings are lifted out by hook-type carriers suspended on the 5,000 ft monorail cooling conveyor, which here runs directly over the mould conveyor, and transferred across a gallery to the ancillary building.

Continuing, the drag flask encounters a pendulum lever, which triggers a pneumatic cylinder to push the flask on to a transverse track to a vibrating shake-out. It is then elevated to the return track to the moulding machines. After the push-off, the mould conveyor pallets are cleared of sand by means of an air-operated, reciprocating, rubber squeegee.

The back-scrap conveyor, which is also fed with material from the primary knock-out line, delivers the metal to a large sprue mill, in which it is tumbled to clear of sand. From the sprue mill, the metal is taken by an apron conveyor to rail wagons for transport to stockbins for re-melting.

Casting treatment

Approximately three hours are spent by the castings on the cooling conveyors traversing the ancillary building and then sand and cores are removed by vibrators and the castings pass to the primary knock-out floor. Risers and feeders are knocked off the castings, while they are still suspended on the conveyor, by hand tools, and the debris falls to the jigging conveyor feeding to the sprue mill.

Primary knock-out and sand removal station

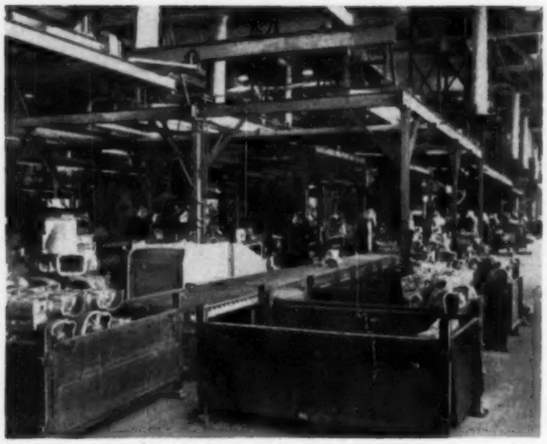
Some of the castings, mainly cylinder blocks and tractor housings, have the end flashings removed from two opposite faces on a battery of 12 duplex disc grinders. These machines, specially developed for the purpose and supplied by Snow & Co. Ltd., have two wheelheads each carrying a 30 in diameter, 23 in bore, ×3 in thick grinding wheel. Spindles are driven by 50 h.p. motors through multiple vee-belts at 760 rev/min, giving a speed of 6,000 ft/min at the periphery of the grinding wheels. A feature of the design is the hydraulic loading of the wheelheads inwards, so that under extreme conditions of grinding they may be forced outwards by the work without sustaining damage.

A cylinder block is loaded in the fixture and hydraulically clamped. When the "Cycle start" lever is operated, the table is traversed hydraulically at a speed of 12 ft/min carrying the workpiece between the two wheels. After a stroke of approximately 48 in, the carriage automatically reverses and returns to the loading position at a speed of 48 ft/min. Grinding time is thus 20 sec, return time 5 sec, and allowing 20 sec for loading and unloading, the floor-to floor time is 45 sec. This operation removes flash of approximately $\frac{3}{4}$ in. to give a rough clean-up to two faces of the cylinder block.

Castings are then returned on two monorail service

Snow duplex grinder for removal of end flash

Castings conveyor from Wheelabrator unit to fettling lines



The fettling department has seven slat-type conveying lines

conveyors in the second gallery to the main building for cleaning and fettling. They are first conveyed through one of two 6-wheel continuous Wheelabrator shot-blasting cabinets and delivered to vibrating shake-out screens at the ends of seven slat-type conveyors. Fettling by hand and by air-operated chisels is carried out on these conveyors.

Some castings, particularly cylinder blocks, require shot blasting on certain oil-retaining walls, for instance, the interiors of crank chambers and tappet chests. Such work is taken off the conveyor lines to one of seven "spot"-type shot-blasting cabinets. In these totally enclosed cabinets is a circular work table that can be elevated to a suitable height and is air-operated, under external pedal control, to turn on its vertical axis through an angle to give blast coverage of the work area.

After inspection, those castings requiring testing for oil and water tightness are passed to one of twelve test stations. They are plugged and filled with water at a temperature of 85 deg F and a pressure 65 lb/in^2. The water contains soda in solution so that a rust-inhibiting film remains on the internal surfaces of the castings after draining and dry-out. The finished castings are then stowed in tote bins ready for trucking to the machine shops in the main Dagenham plant.

Air conditioning

No trouble, expense, or equipment has been spared in the provision of the clean, healthy and comfortable working conditions which are regarded as an essential factor in obtaining and maintaining a high productivity rate. The pressure-ventilating, temperature-regulating, and air-purifying systems are quite outstanding in their scope and their scale. The whole air content of the buildings is changed at the rate of seven times an hour. In moulding and fettling departments and other specific areas, the rate is locally increased to as many as sixteen times an hour.

All air entering the building is filtered and delivered through screens of tubes for warming in winter and cooling in summer. Steam heaters around the perimeters of the buildings and over main aisles and doorways compensate for heat losses. Fans and windows are thermostatically controlled to adjust in response to temperature variations.

Exhaust systems draw off dust, fumes and smoke at source and so prevent their dispersal within the buildings. The entire system, one of the largest installations in this country, was undertaken by Air Control Installations Ltd. The twenty-six Type N Roto-Clone hydrostatic precipitators employed in the exhaust system handle 42,000,000 ft^3 of air per hour. Besides collecting the dust and fumes at source, they thoroughly scrub out foreign matter before discharging the cleaned air to atmosphere. Approximately 35 tons of sludge are taken each day from the Roto-Clone units.

Twelve of the Roto-Clones are mounted on the roof of the main building, and control the dust from the moulding and shake-out area, core grinders, spot blast cabinets and Wheelabrators. They are fed by a total quantity of 800 gallons of water per minute, and continuously discharge the collected material in the form of a slurry at the same rate to a gravity-type central sluicing system. All is led to two large settling tanks, from whence the water overflows to cooling ponds before being re-circulated to the sluice-way.

A further fourteen Roto-Clones are at ground level outside the ancillary building and these control the dust at the primary knock-out section, vibrating knock-outs, grinders and back-scrap separation plant. These Roto-Clones have built-in conveyors which continuously eject the collected material as sludge to skips for mobile transfer to the settling tanks. After the initial filling of their sludge tanks, they require only sufficient water to make up for that lost by evaporation and in the ejected sludge.

Roto-Clone installation alongside ancillary building

FORD strides ahead

. . . and the new Foundry at Dagenham, with its superb equipment and fine working conditions, offers powerful evidence of progress in Ford's modernisation programme, a plan for development unequalled by any other manufacturer in Europe. Here's a vote of confidence in Britain's future, a foundation for greater vehicle exports, and a promise of even more value for money for Ford owners everywhere.

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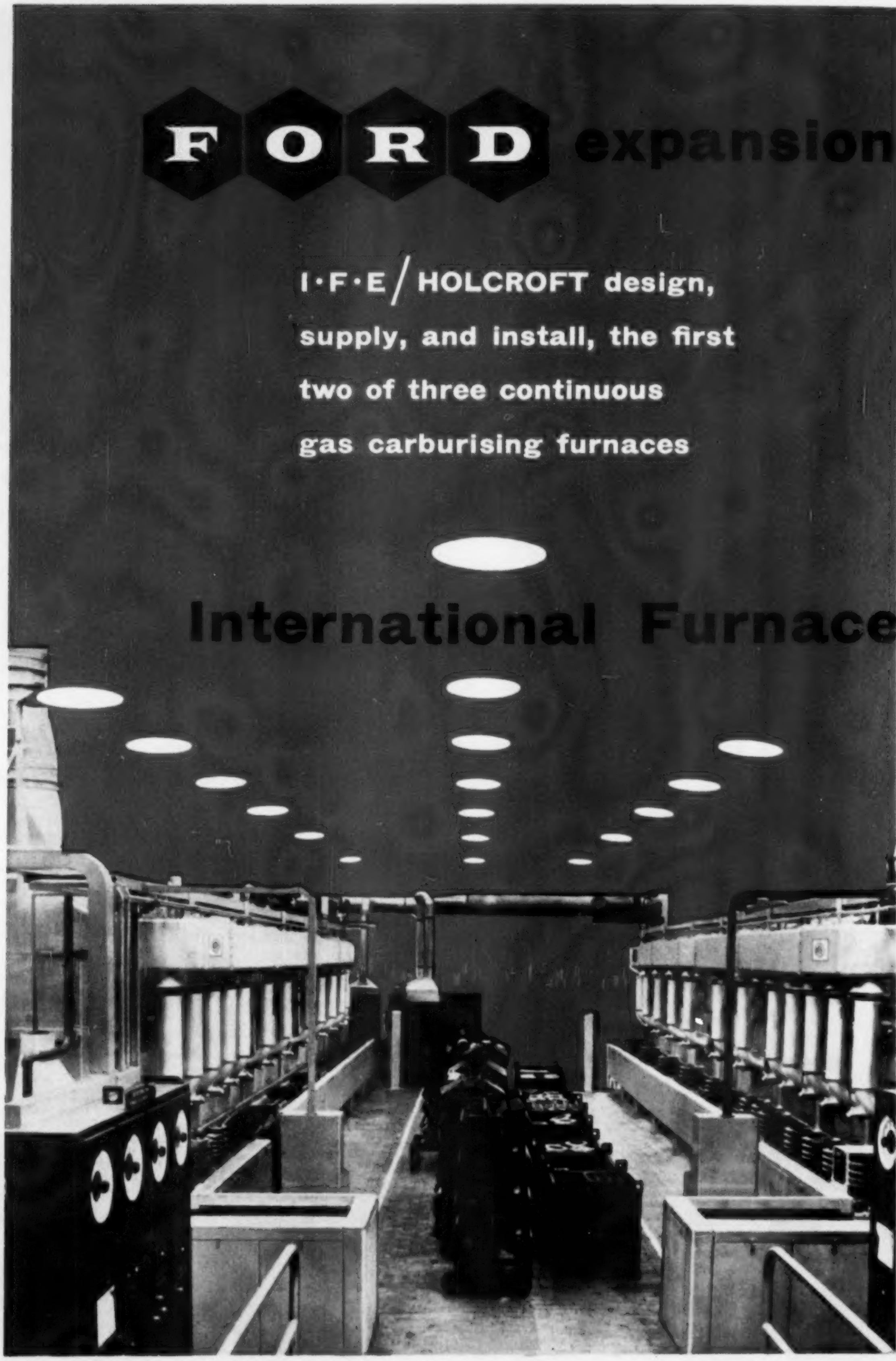
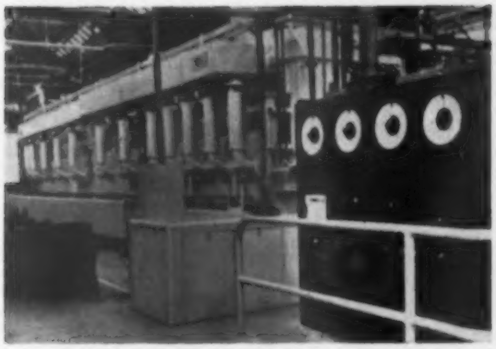
FORWARD WITH FORD OF DAGENHAM

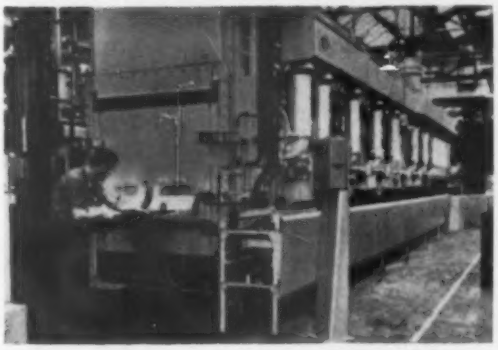

FORD expansion
I·F·E / HOLCROFT design,
supply, and install, the first
two of three continuous
gas carburising furnaces
International Furnace

programme . . .



I.F.E. in association with Holcroft & Company, Detroit, were responsible for the design, supply and installation of two, twin track pusher type direct discharge furnaces for press quench operations. These furnaces set a new standard of construction for continuous gas carburising plant. Simpler to maintain, and with increased thermal efficiency, they are, apart from loading and unloading operations, completely automatic.

Equipment Ltd.



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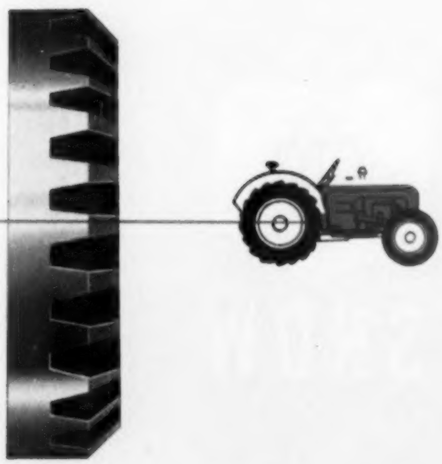


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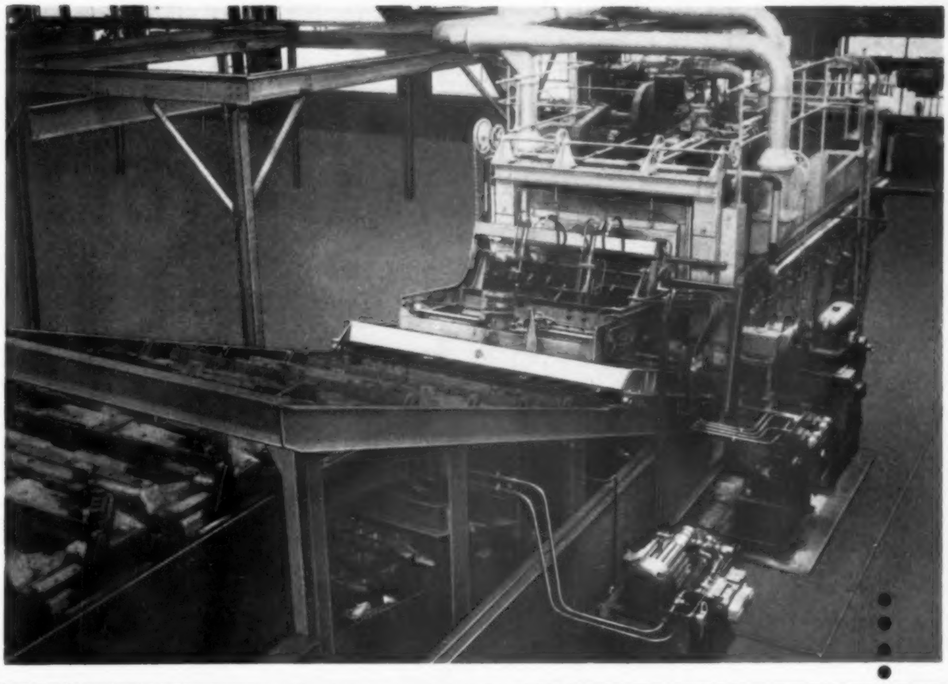

IFE and the FORD expansion scheme

I.F.E. Holcroft design, build and install the Spring Hardening Furnace for Commercial Vehicle Road Spring Sets.

The automatic discharge machine loads heated springs into indexed forming jigs which are part of the quench tank.

Small illustration shows entrance of coke oven gas fired continuous chain conveyor type furnace. The movements of the special jig quench conveyor are fully co-ordinated with the movements of the furnace conveyor and discharge machine.

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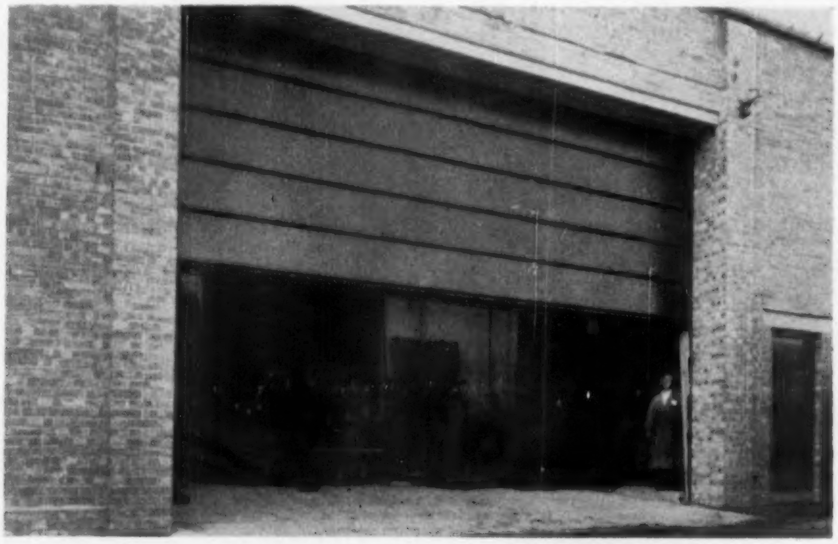

JACKMAN-BUILT OSBORN MACHINES
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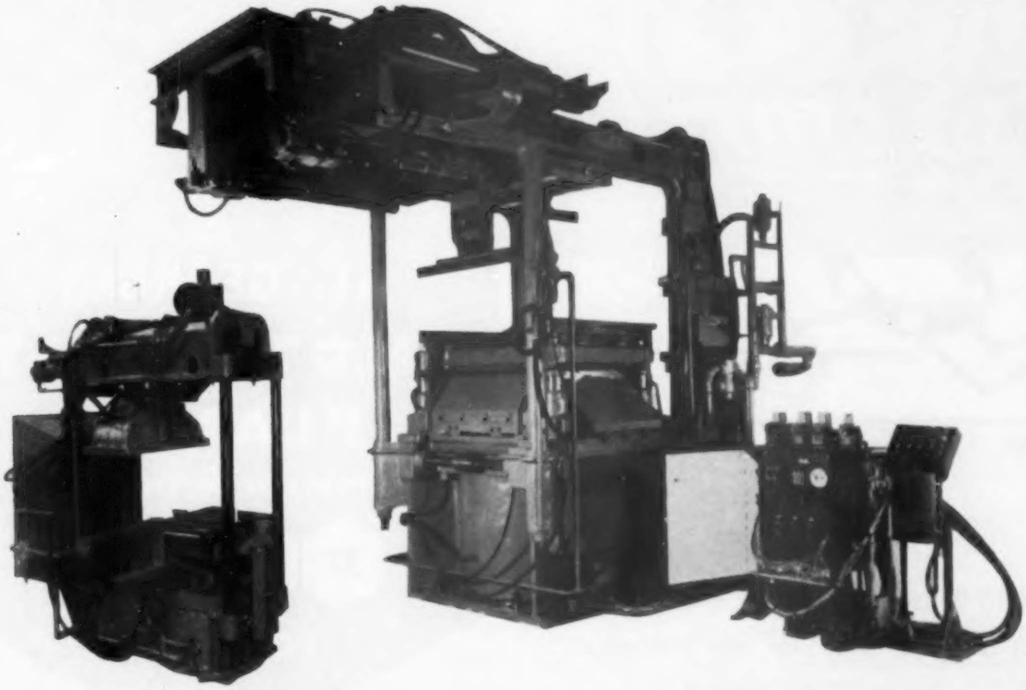

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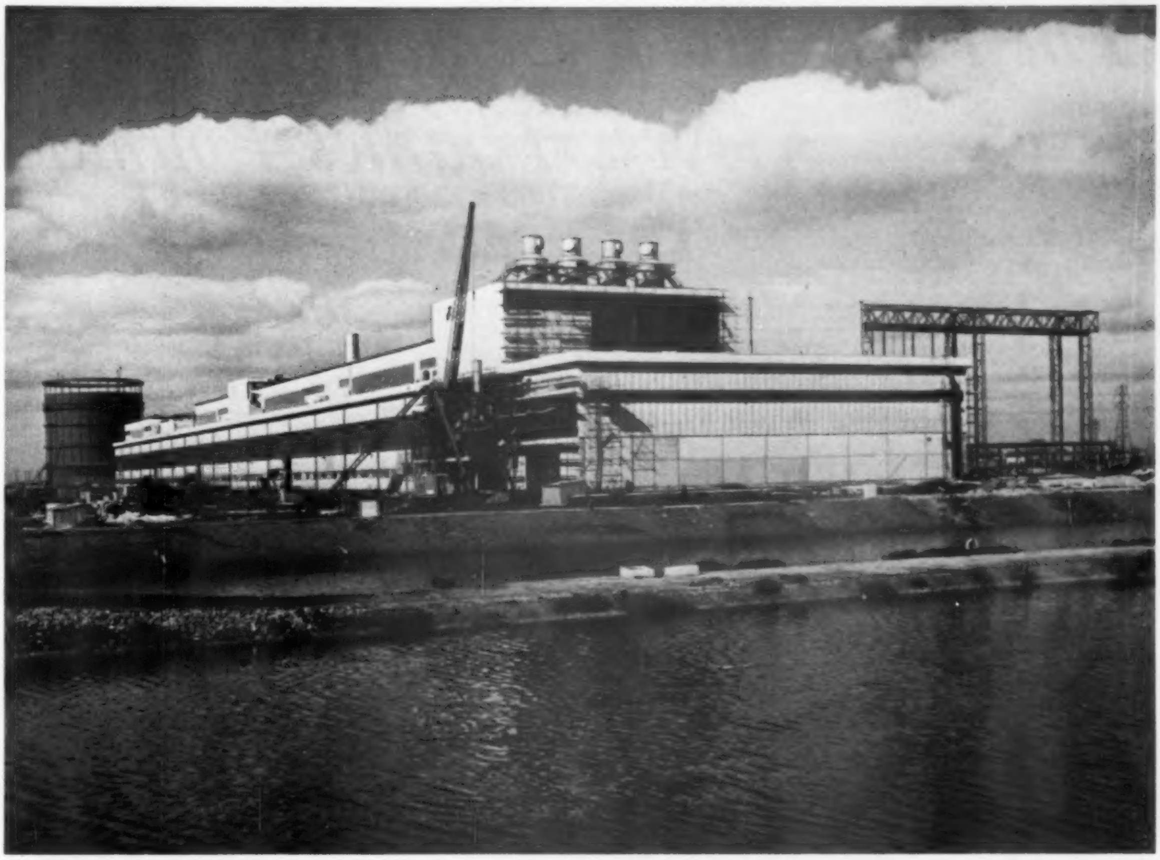

The Ford Foundry at Dagenham.

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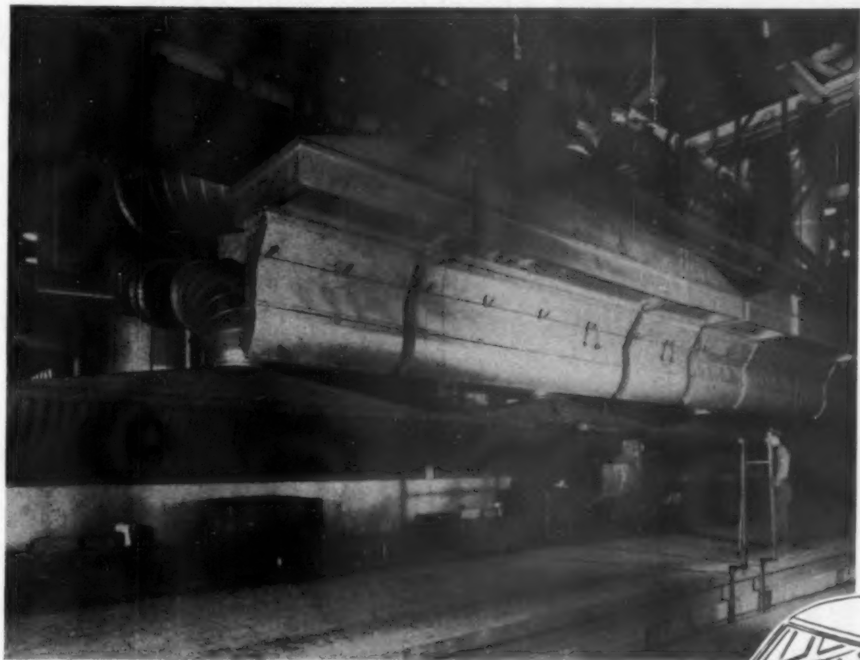

Fume extraction and compensating air hoods in the pouring bay

The Holmes-Schneible System installed at the new Ford Foundry removes more than half a million cubic feet of dust and fume laden air per minute, thus ensuring optimum working conditions twenty-four hours per day. In addition over 200,000 cubic feet of clean air per minute are supplied at certain points as 'compensating air' to maintain the foundry heating balance.

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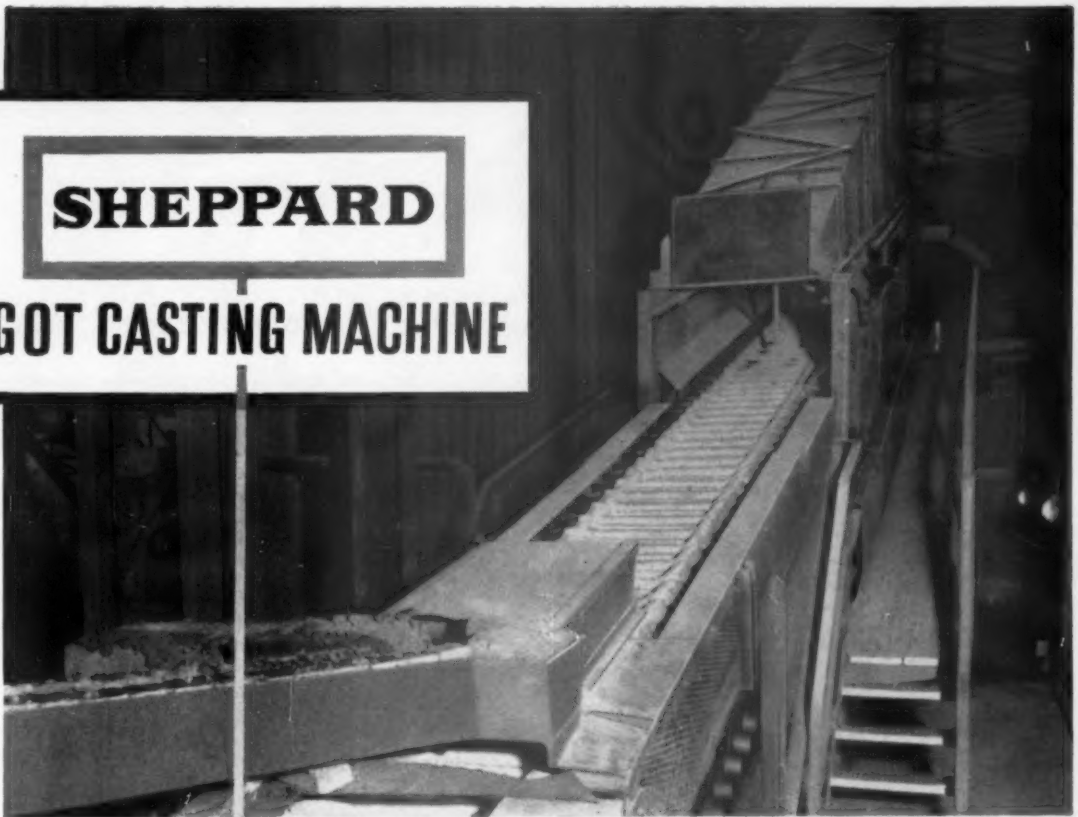

(Photograph by courtesy of Ford Motor Co. Ltd.).

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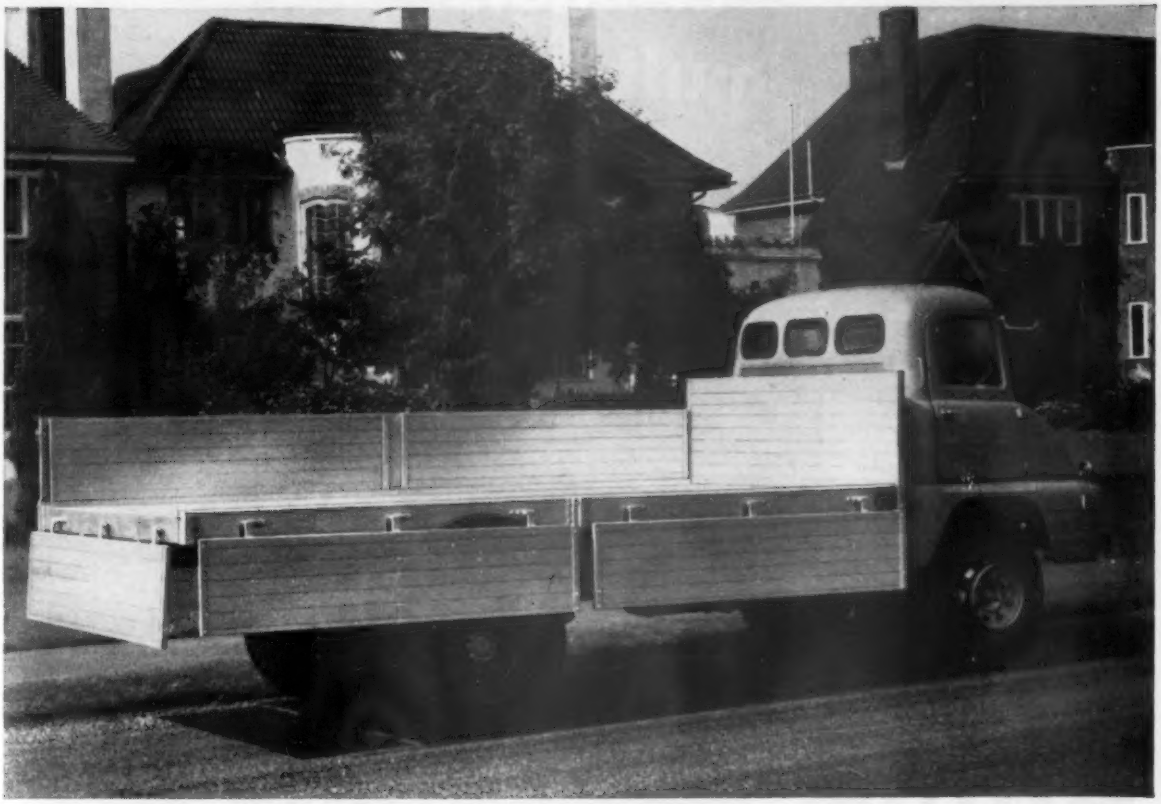

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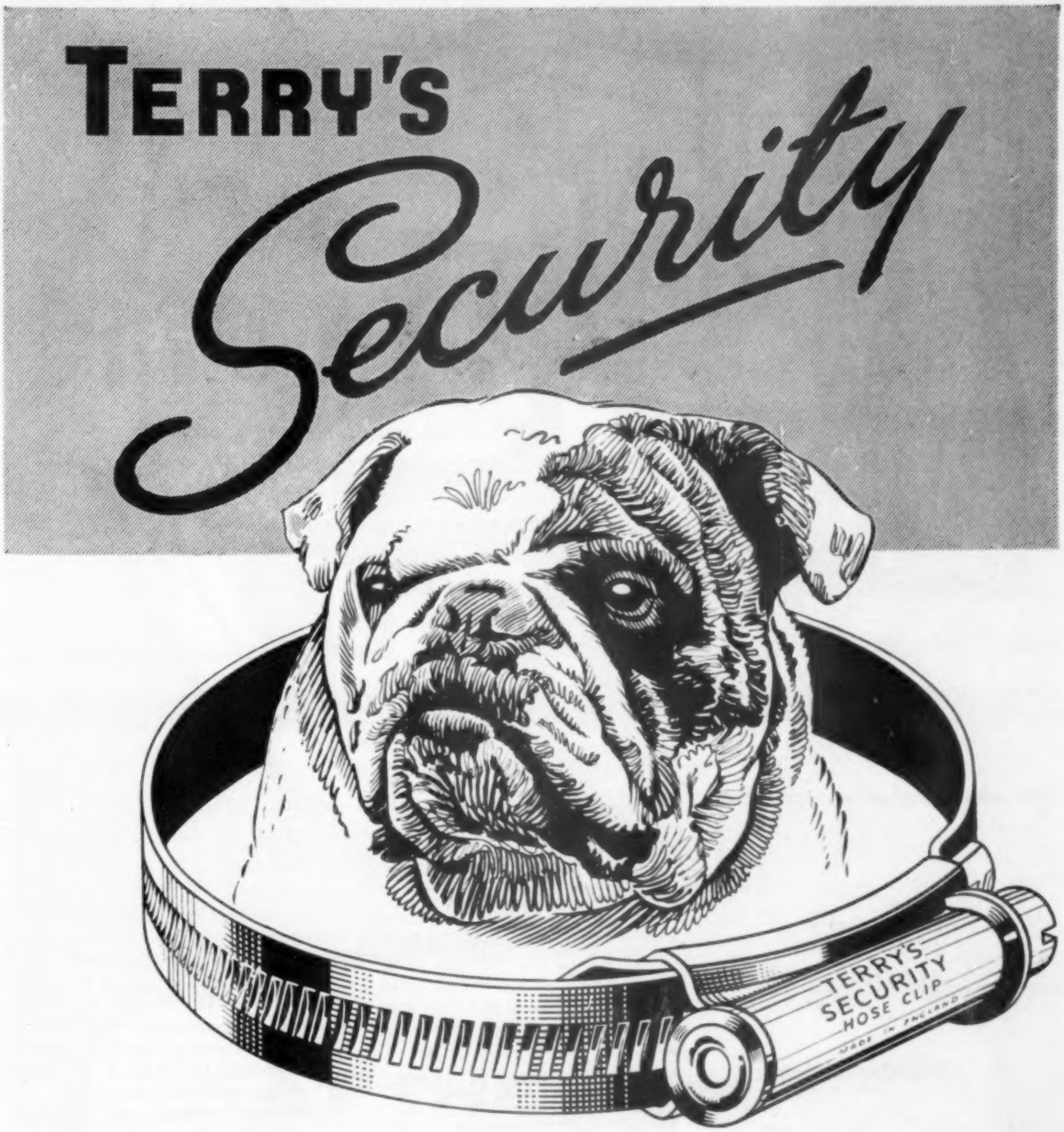

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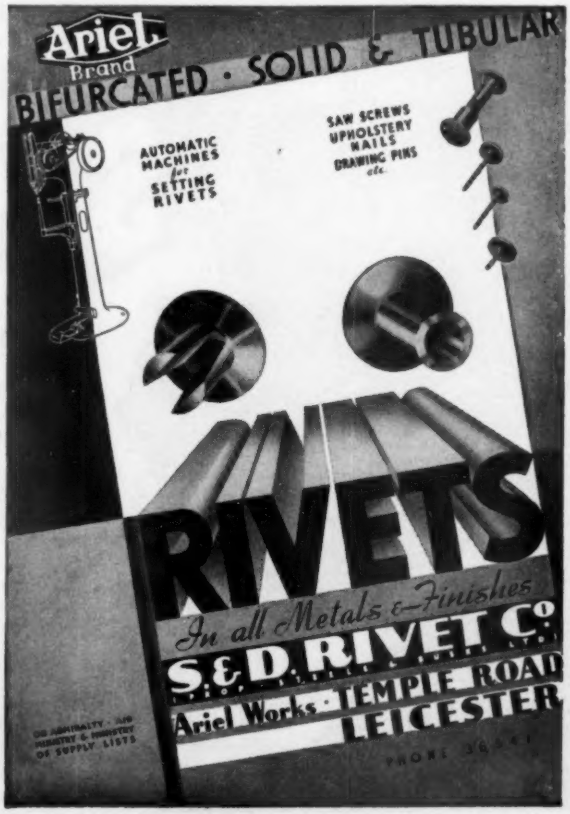

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For full details of this and other machines in the range send for Leaflet T.32

The Ford Zodiac saloon.

The illustrations :—
Top left : Loading conveyor.
Centre : General view, front of plant.
Lower right : Discharge drum and conveyor.

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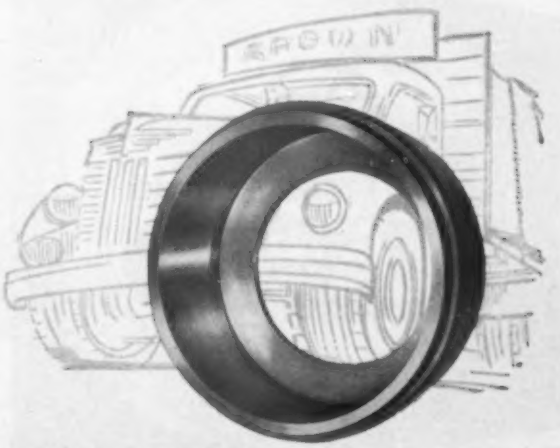

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